Die Blei-Blei Methoden

Pb produced by radioactive decay of U & Th

$^{238}U \rightarrow {}^{206}Pb$ (half-life 4.47 Ga)

$^{235}U \rightarrow {}^{207}Pb$ (half-life 0.70 Ga)

$^{232}Th \rightarrow {}^{208}Pb$ (half-life 14 Ga)

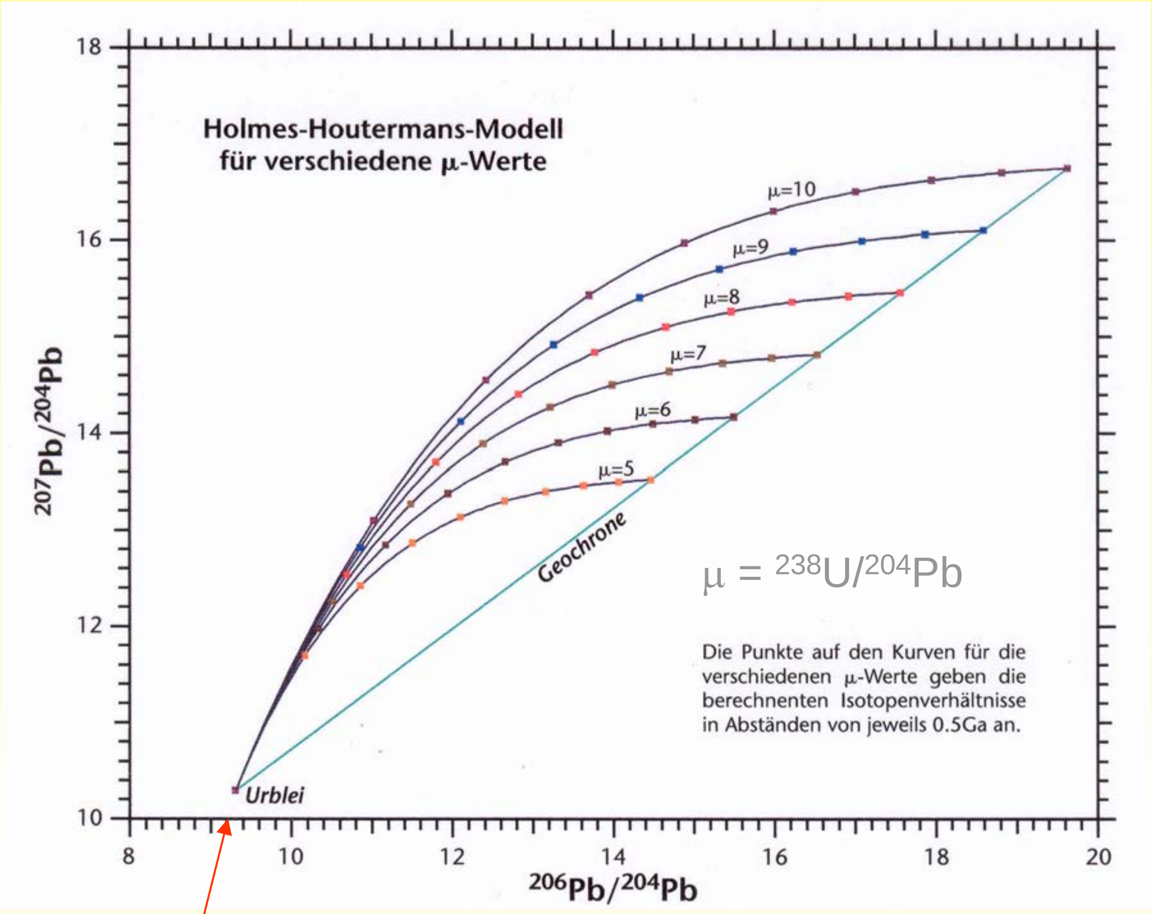
non-radiogenic ^{204}Pb used as reference

so, increase of $^{208}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$,

due to U and Th decay

$$\frac{\Delta^{207}Pb/^{204}Pb}{\Delta^{206}Pb/^{204}Pb} = \frac{^{235}U\left(e^{\lambda_{235}t}-1\right)}{^{238}U\left(e^{\lambda_{238}t}-1\right)}$$

The isotope geology of lead



$$\left(\frac{{}^{206}Pb}{{}^{204}Pb}\right)_t = a_0 + \mu\left(e^{\lambda_1 T} - e^{\lambda_1 t}\right)$$

$$\left(\frac{{}^{207}Pb}{{}^{204}Pb}\right)_t = b_0 + \frac{\mu}{137.88}\left(e^{\lambda_2 T} - e^{\lambda_2 t}\right)$$

$$\left(\frac{{}^{206}Pb}{{}^{204}Pb}\right)_i = a_0 = 9.30$$

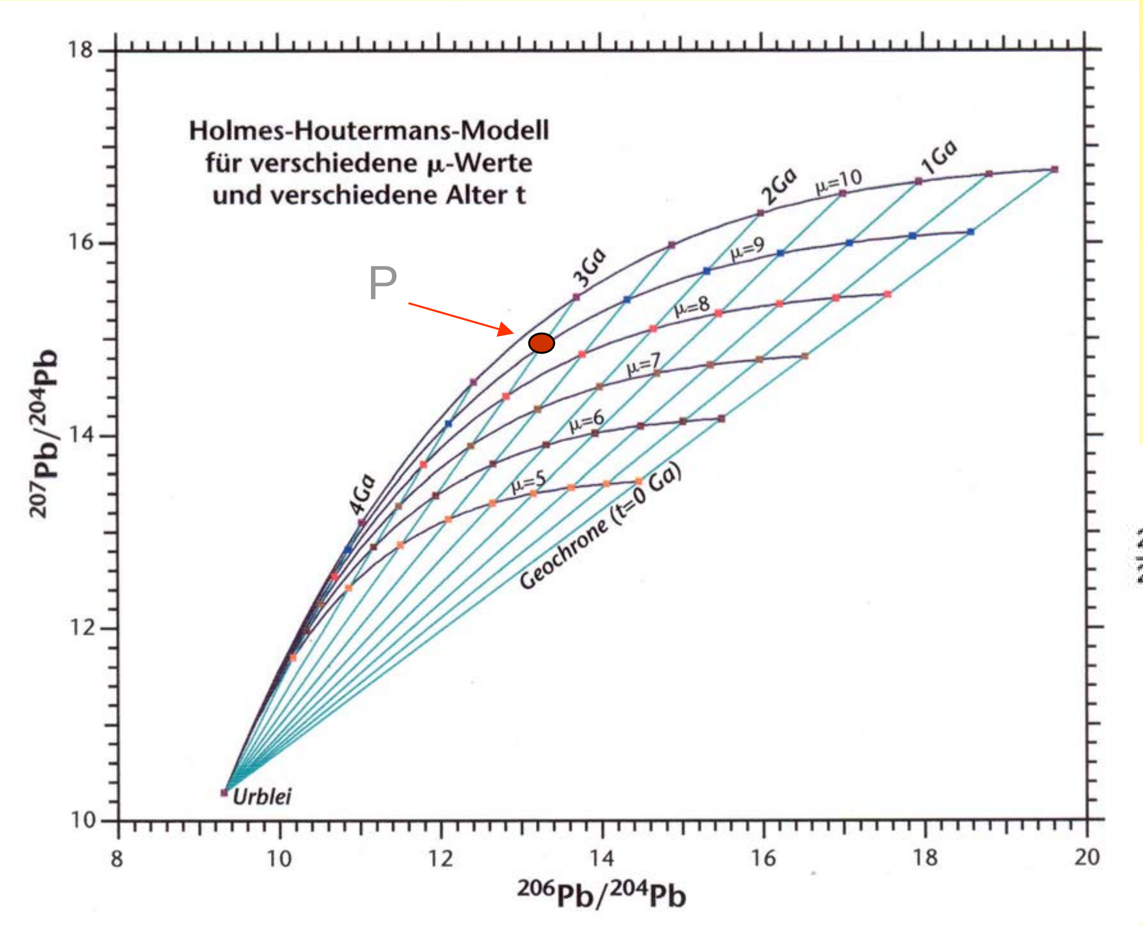
$$\left(\frac{{}^{207}Pb}{{}^{204}Pb}\right)_i = b_0 = 10.29$$

Dalrymple: "the hourglass of the solar system"

Primeval lead

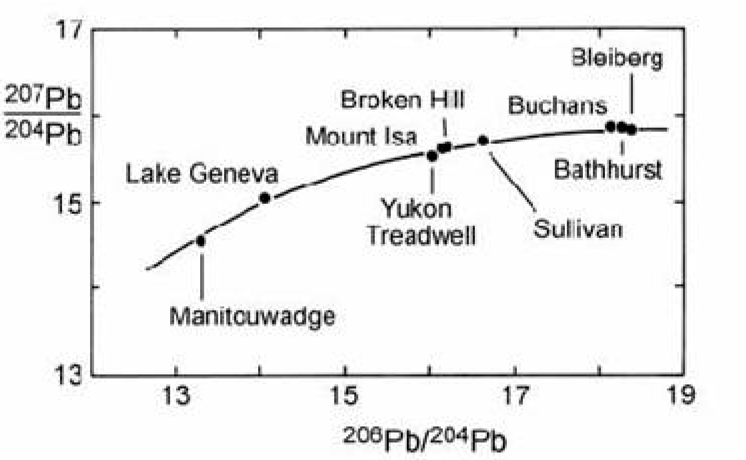
(Isotope ratios of Pb in troilite of the iron meteorite Canyon Diablo)

The isotope geology of lead



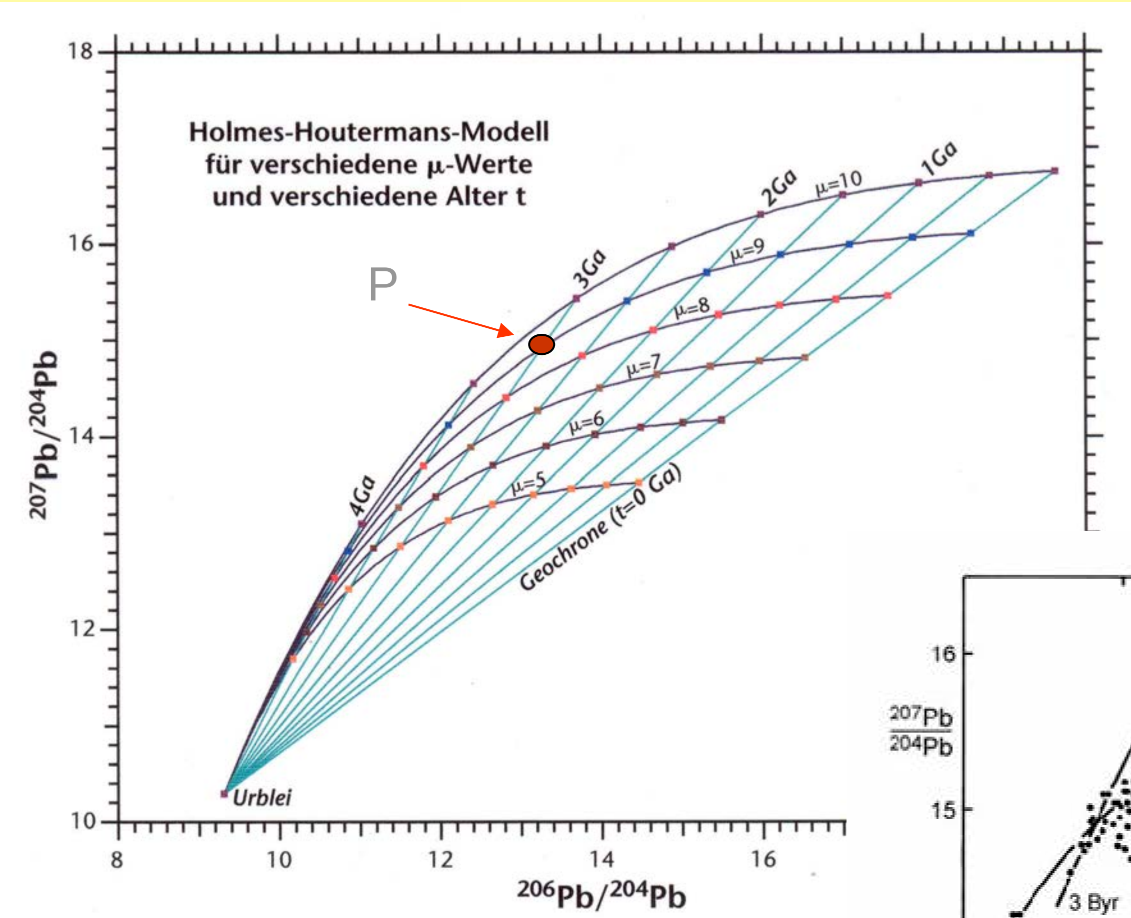
$$\left(\frac{^{206}Pb}{^{204}Pb}\right)_t = a_0 + \mu(e^{\lambda_1 T} - e^{\lambda_1 t})$$

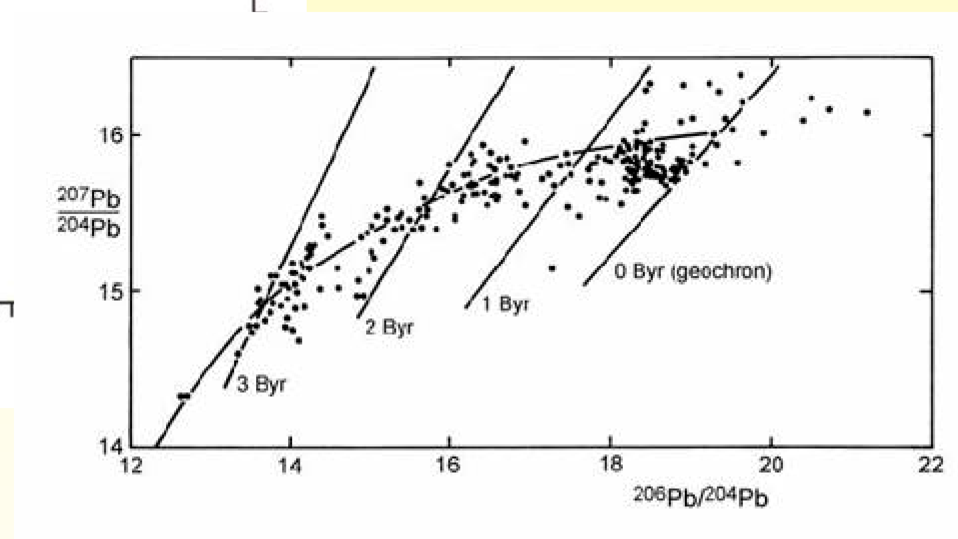
$$\left(\frac{^{207}Pb}{^{204}Pb}\right)_t = b_0 + \frac{\mu}{137.88}(e^{\lambda_2 T} - e^{\lambda_2 t})$$



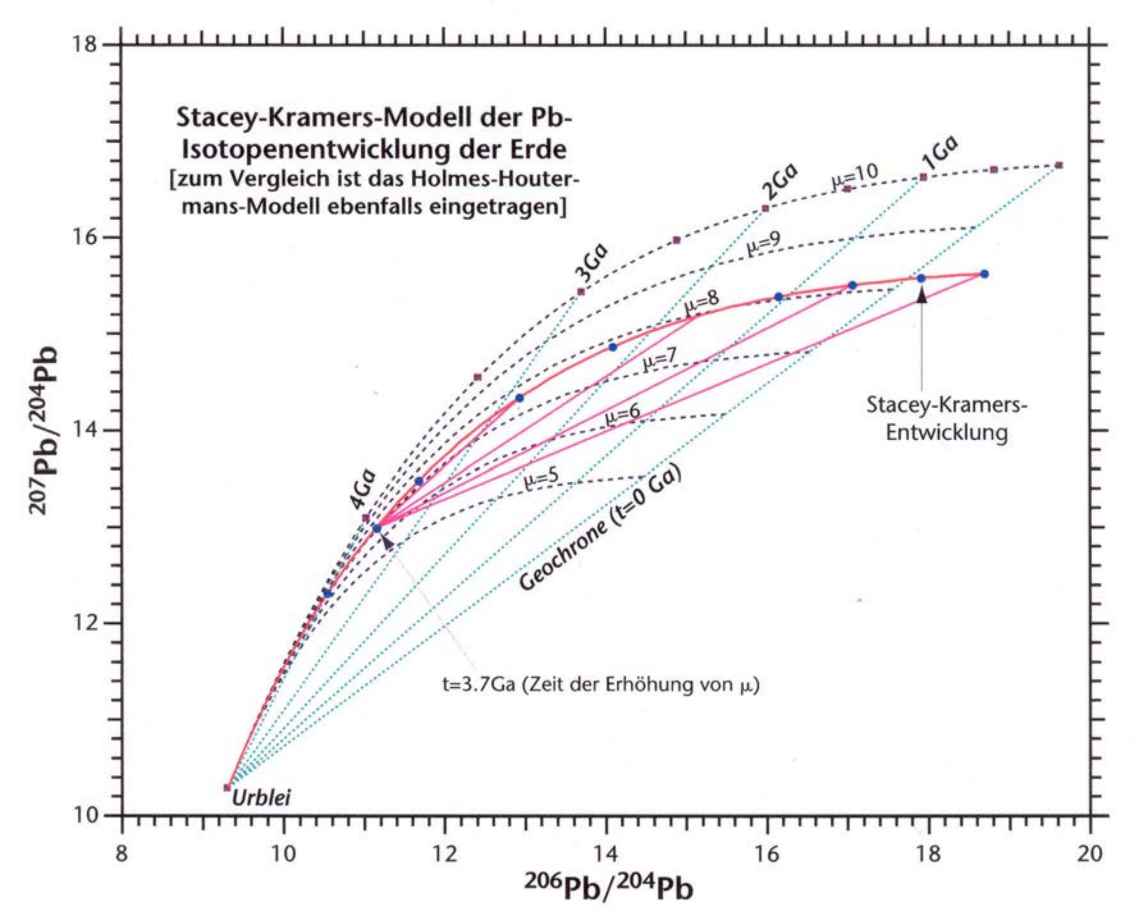
galena ores that form the basis of the 'conformable' Pb model

The isotope geology of lead





The isotope geology of Pb



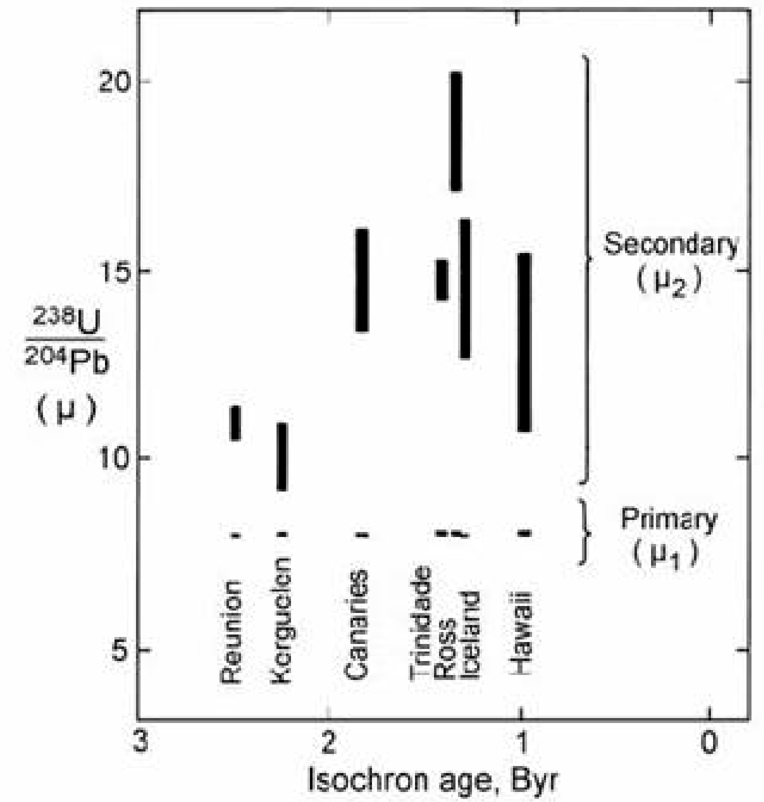
Two-stage Pb evolution (Stacey & Kramers 1975)

Pb evolves from primordial isotope ratios between 4.6 and 3.7 Ga in a reservoir with a μ-($^{238}U/^{204}Pb$) value of 7.2

At 3.7 Ga the μ-value of the reservoir was changed by geochemical differentiation to 9.7

The isotope geology of Pb

Range of values required to explain OIB sources using a two-stage Pb evolution model. Parental mantle (μ_1) undergoes differentiation events at different times to yield discrete OIB source domains (μ_2).



Chase (1981)

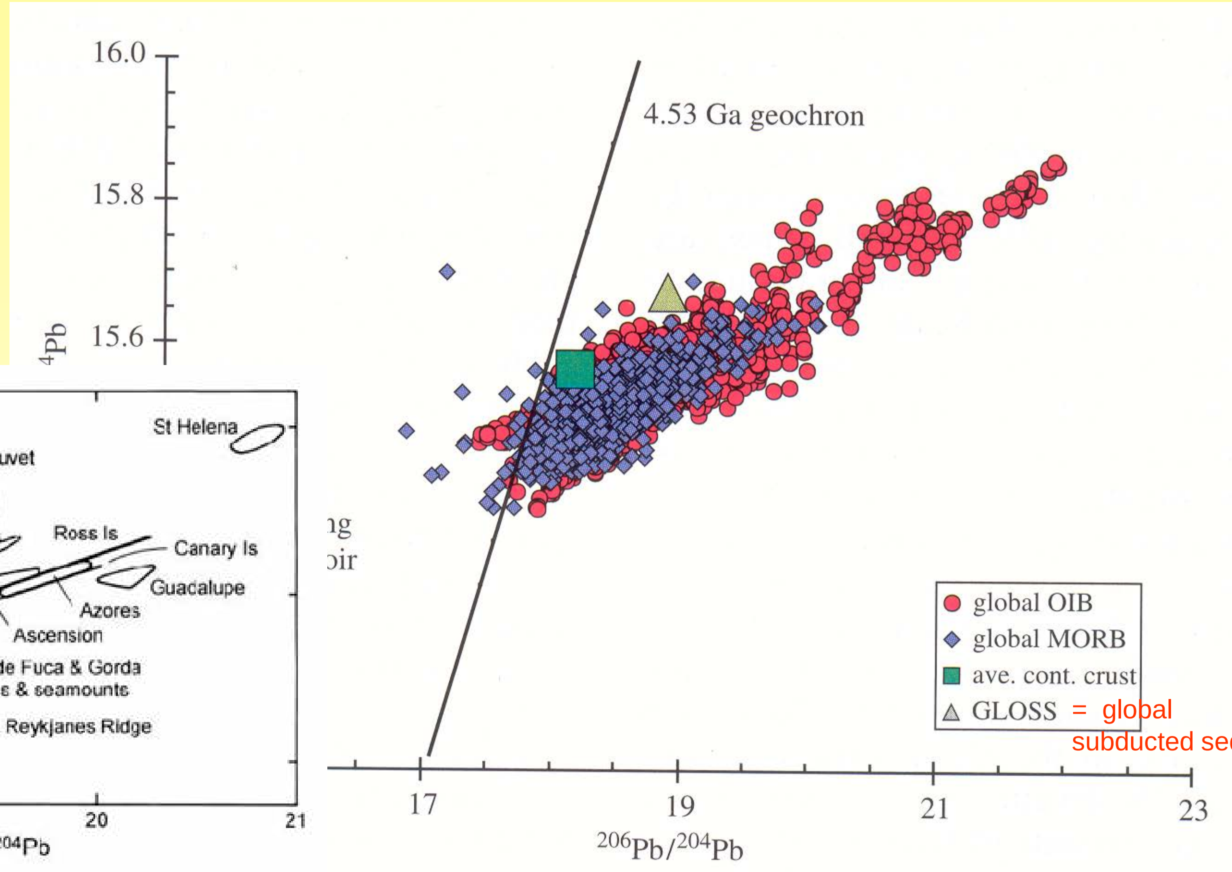
http://www.onafarawayday.com/Radiogenic/Ch6/Ch6-3.htm

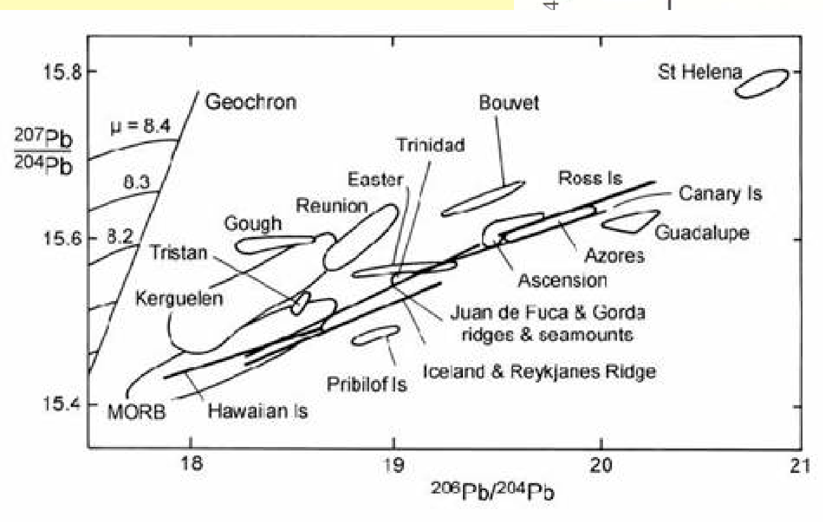
The lead isotope paradox

Crust and mantle:

complementary in terms of Pb-contents

but similar isotopic composition

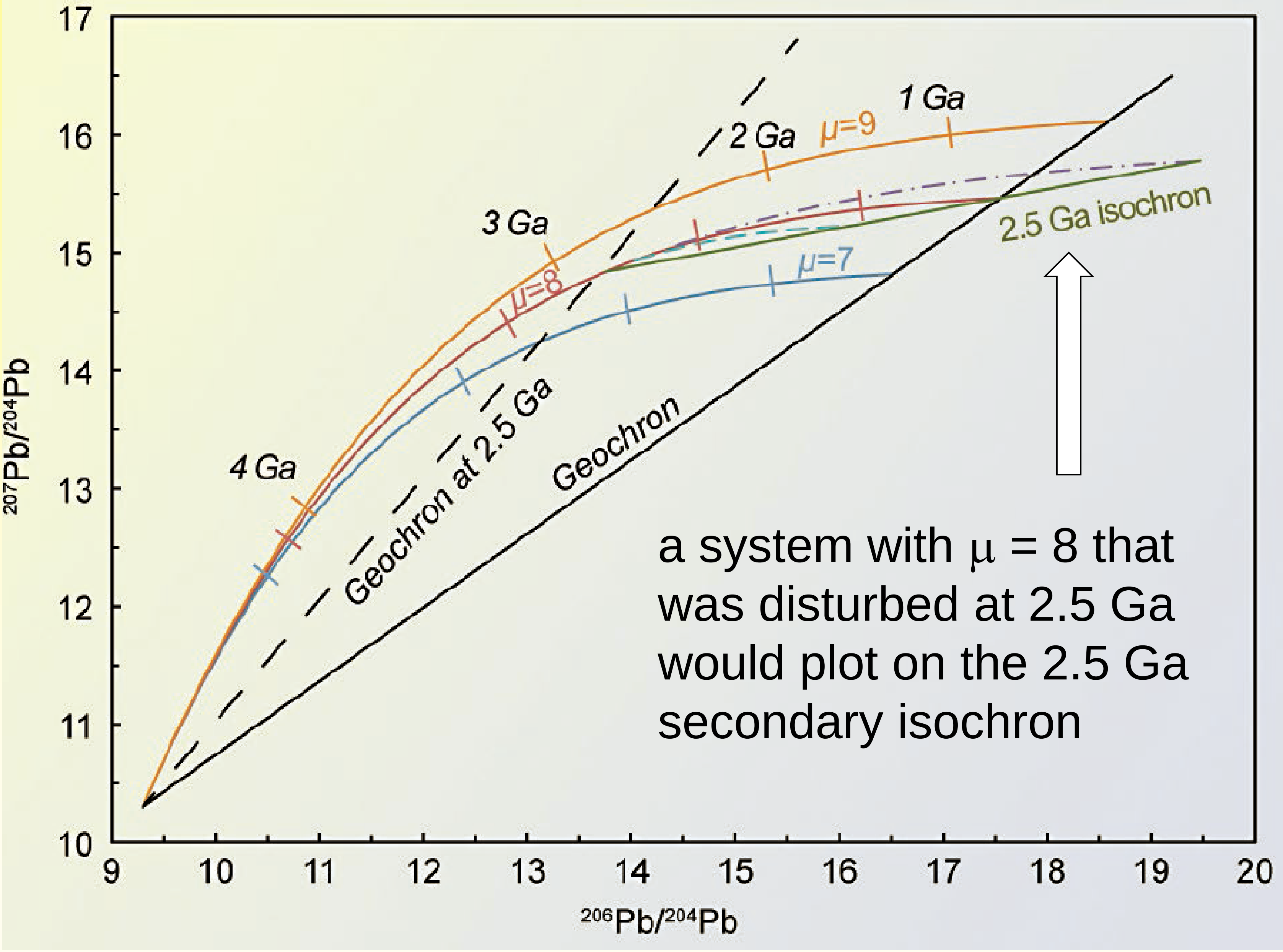




The fact that MORBs do not plot to the left of the geochron is called the “First terrestrial lead isotope paradox”

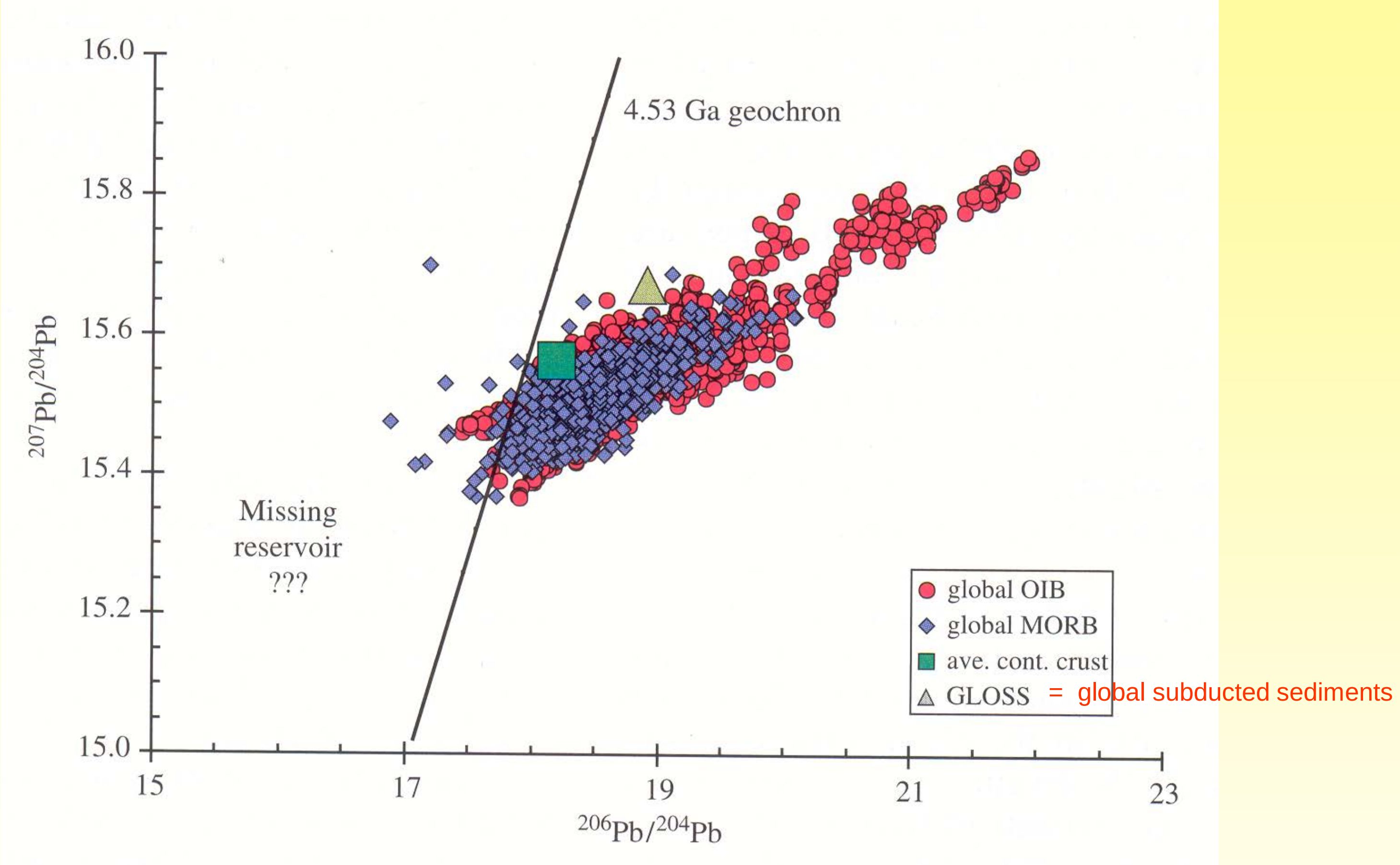
Hofmann (2003) : Treatise on Geochemistry

The isotope geology of lead



a system with μ = 8 that was disturbed at 2.5 Ga would plot on the 2.5 Ga secondary isochron

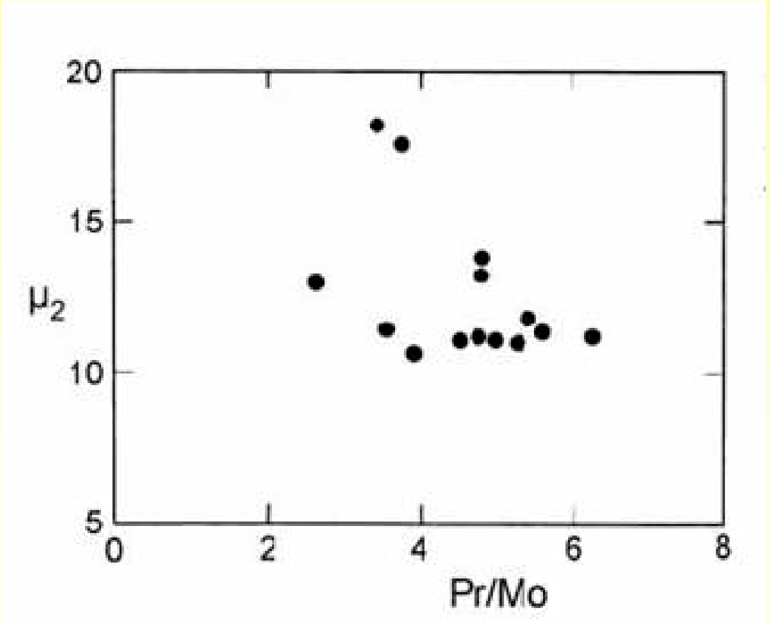
Das Pb-Paradox



- uptake of lead by the core (“core pumping”)

Das Pb-Paradox

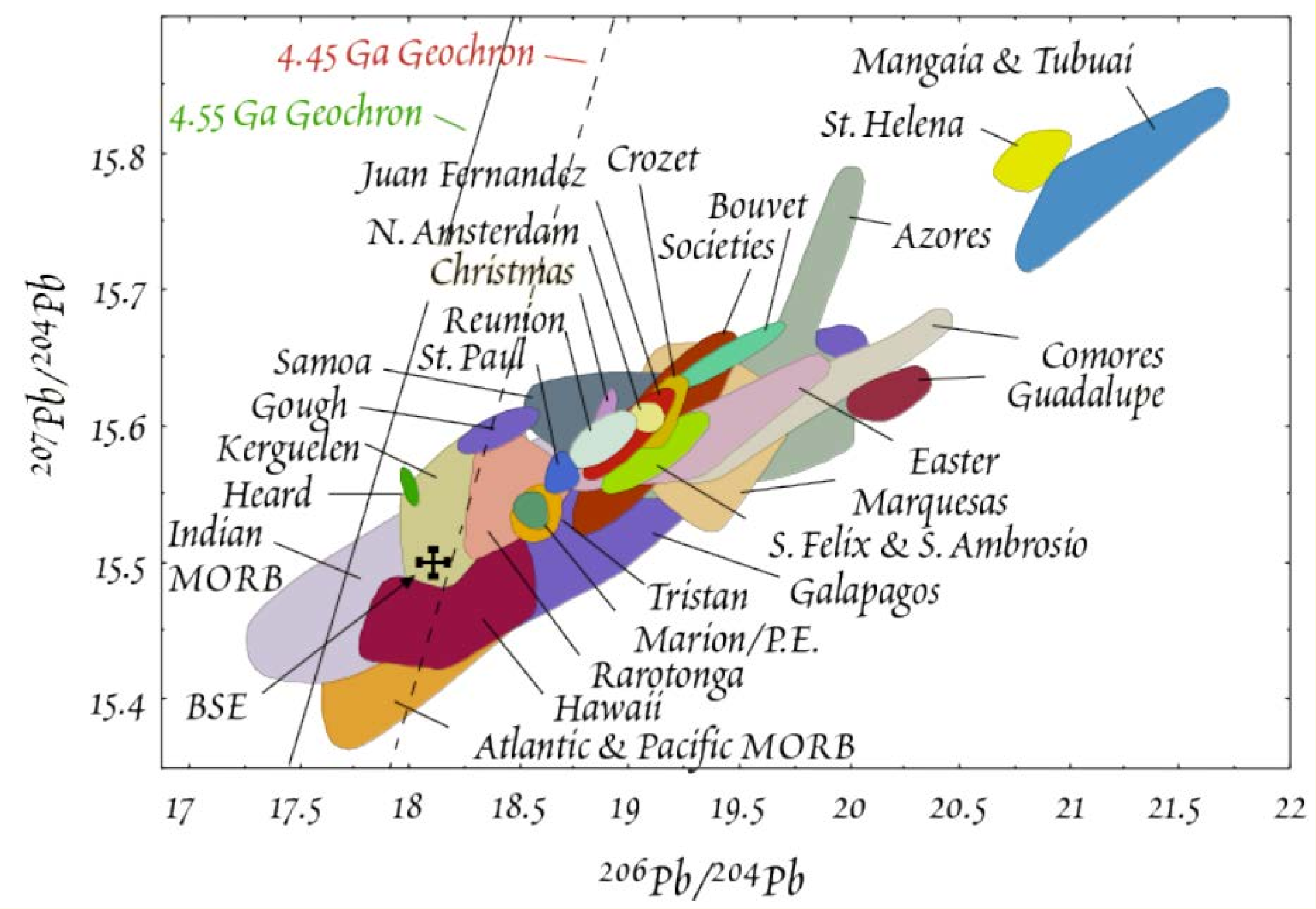
Core Pb-pumping model (Allègre *et al.*, 1982) relies on the assumption that during core formation, Pb was partitioned into the core whereas U became enriched in the silicate Earth → increase of μ-value



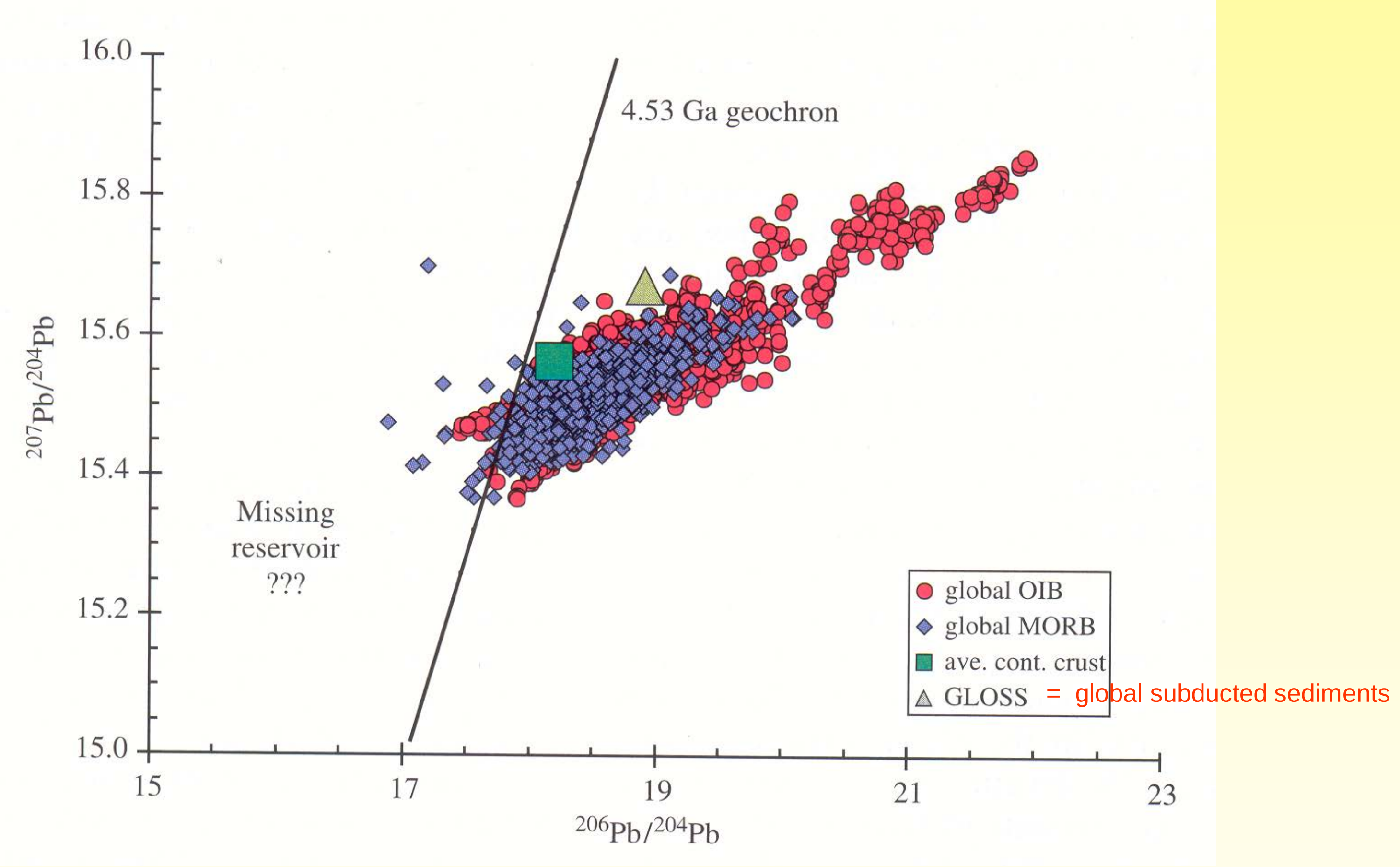
Lagos et al. (2008) The Earth's missing lead may not be in the core. Nature 456

Core pumping theory evaluated by Newsome et al. (1986)

Das Pb-Paradox

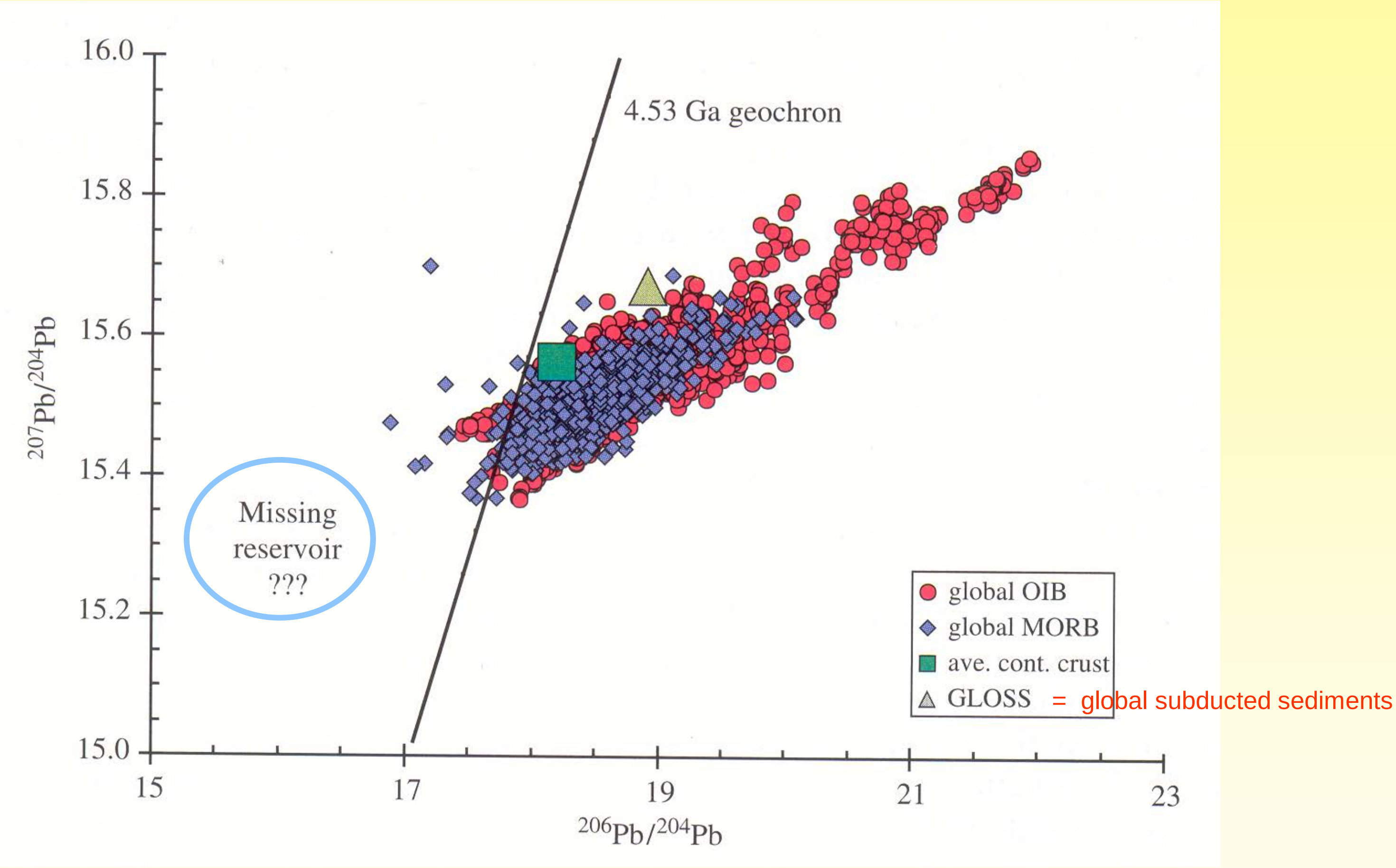


Das Pb-Paradox



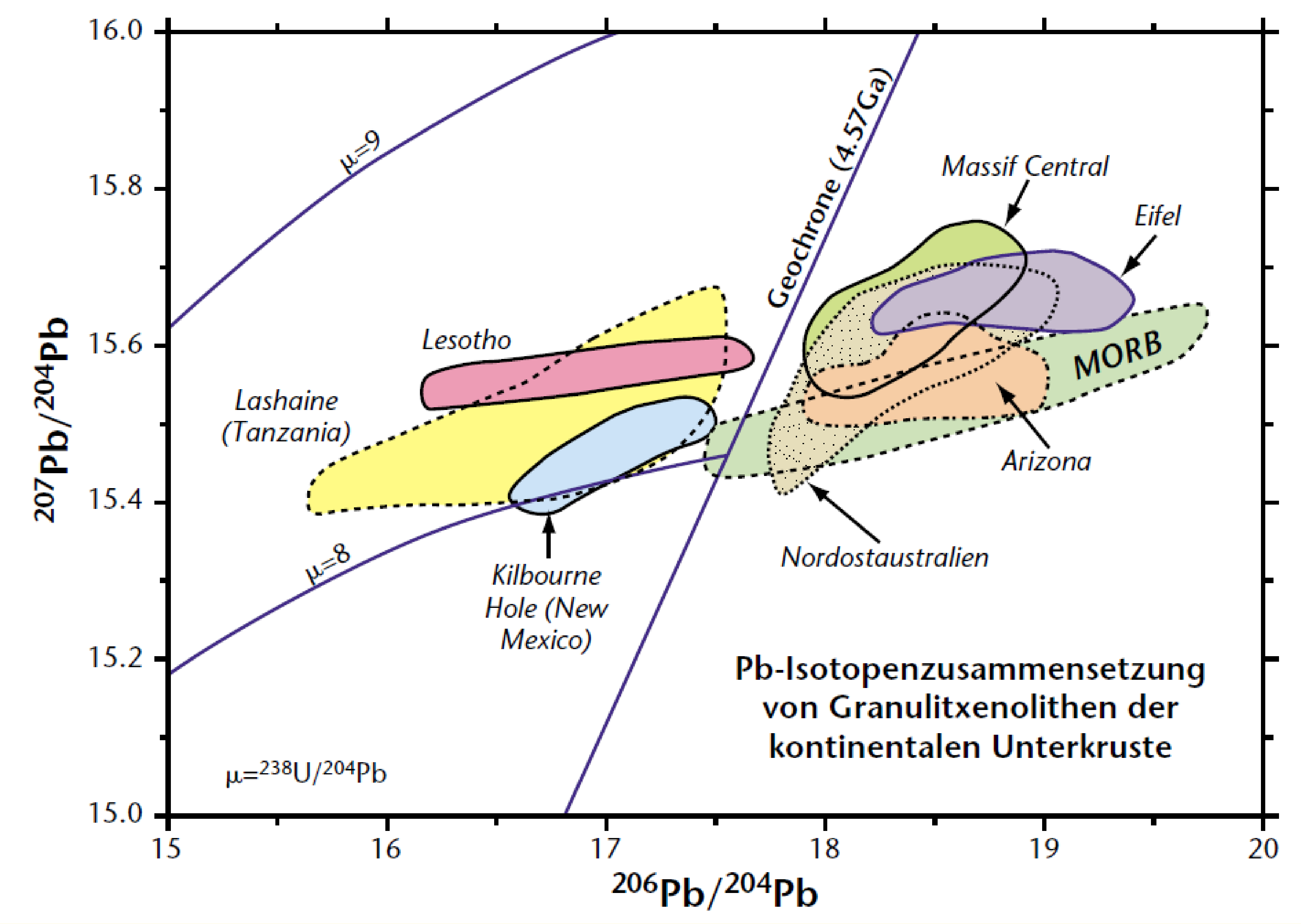
- storage of unradiogenic lead in the lower cont. crust or subcont. lithosphere

Das Pb-Paradox



hidden reservoir with Pb isotopes to the left of the geochron

Das Pb Paradox

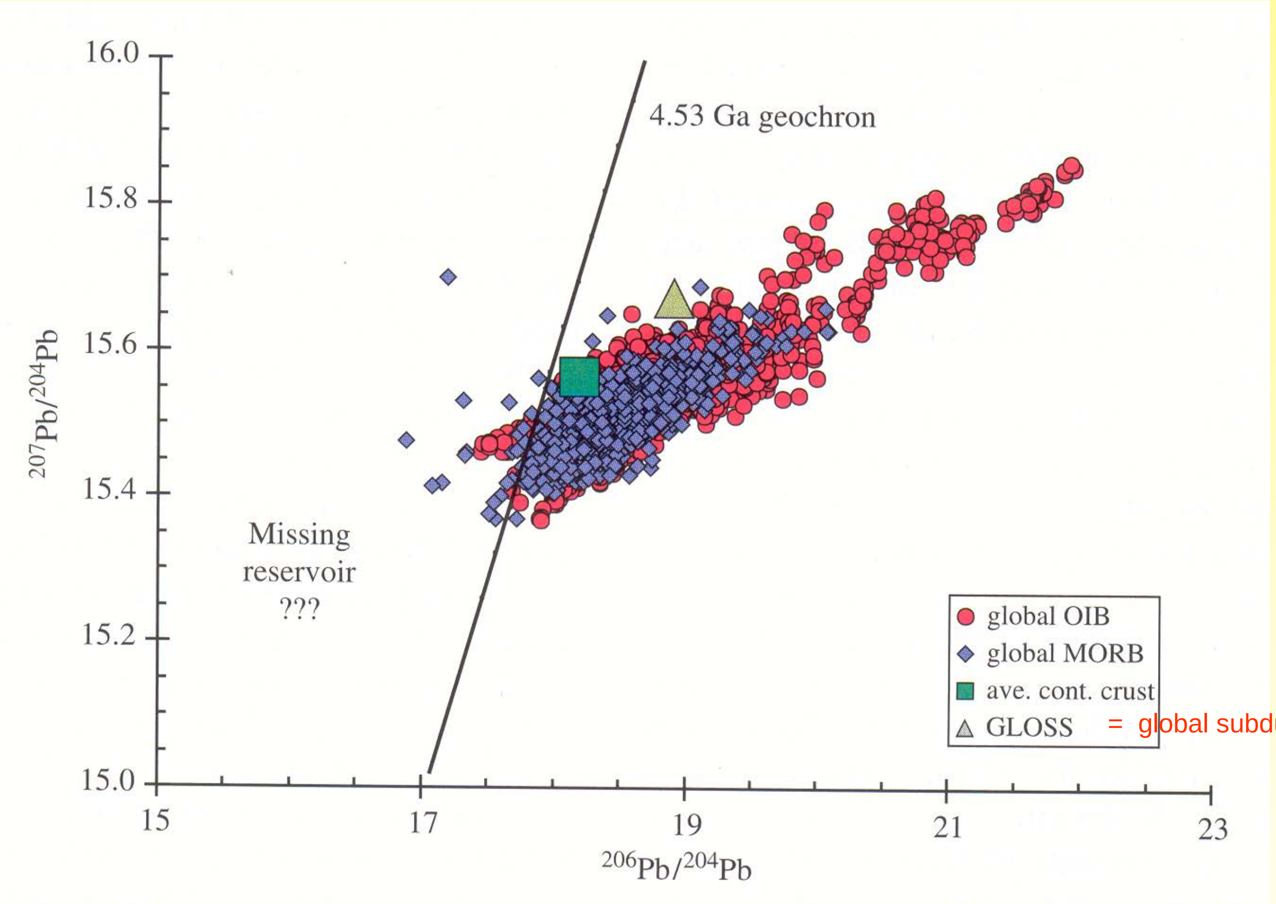


Das Pb-Paradox

Crust and mantle:

complementary in terms of Pb-contents

but similar isotopic composition



= global subducted sedim

Ave. oceanic and cont. crust close to geochron
→ little net fractionation of U/Pb during
crust-mantle differentiation

The terrestrial Th/U ratio, κ

$$^{208}Pb^* = {}^{232}Th(e^{\lambda_{232}t} - 1)$$

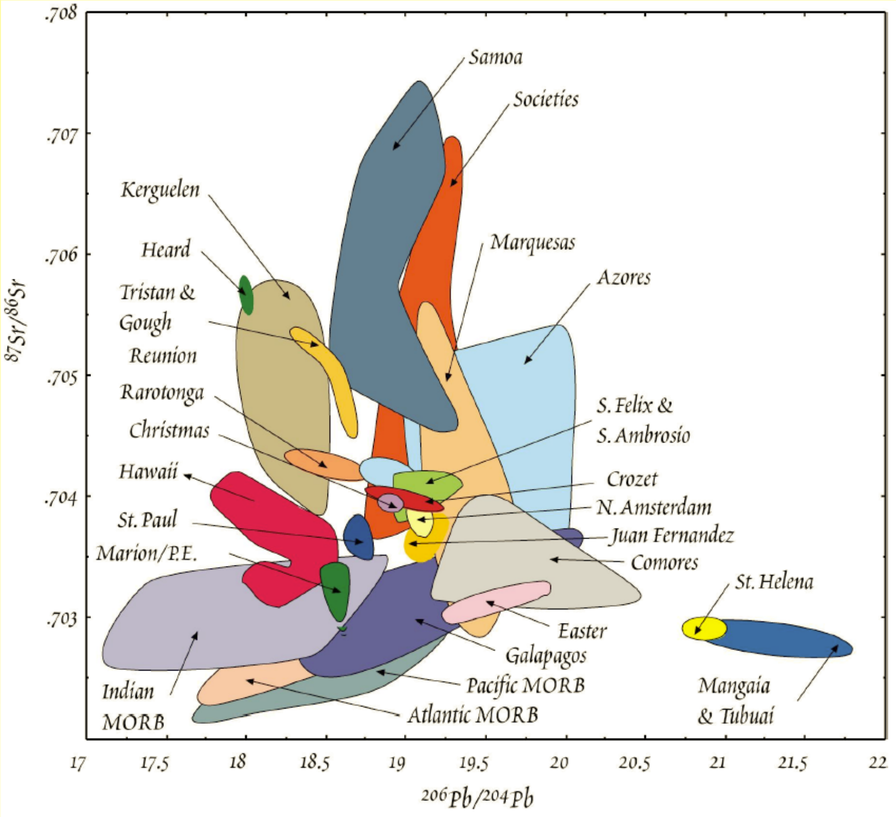
$$^{206}Pb^* = {}^{238}U(e^{\lambda_{238}t} - 1)$$

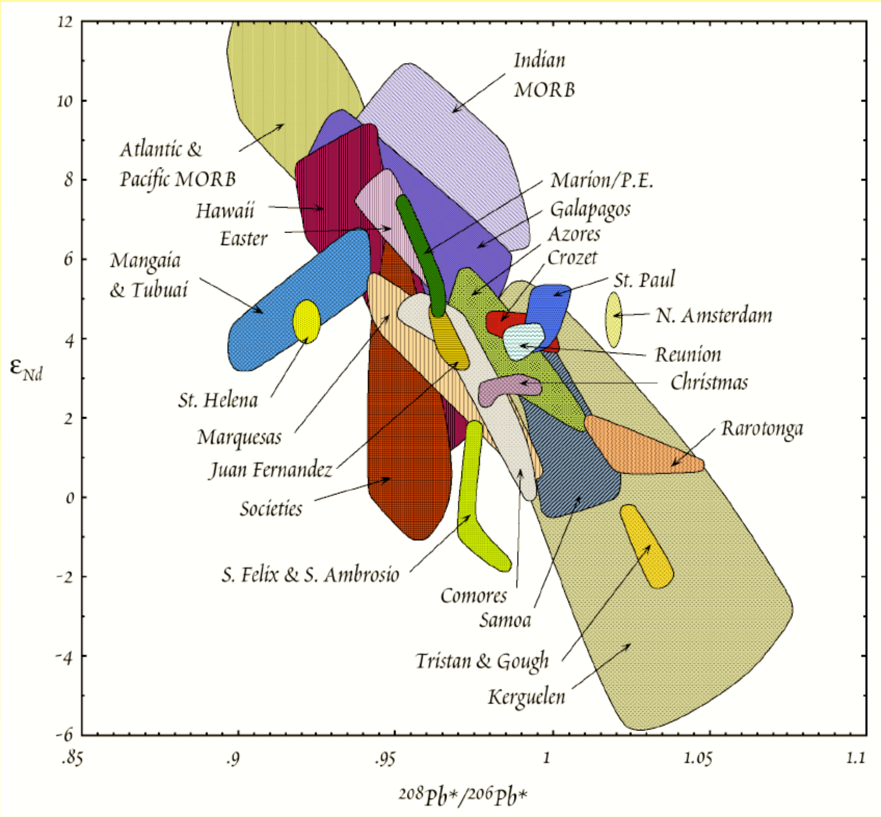
$$\frac{^{208}Pb^*}{^{206}Pb^*} = \frac{^{232}Th}{^{238}U} = \kappa \frac{(e^{\lambda_{232}t} - 1)}{(e^{\lambda_{238}t} - 1)}$$

$$^{208}Pb^*/^{206}Pb^* = \frac{(^{208}Pb/^{204}Pb)_t - (^{208}Pb/^{204}Pb)_T}{(^{206}Pb/^{204}Pb)_t - (^{206}Pb/^{204}Pb)_T}$$

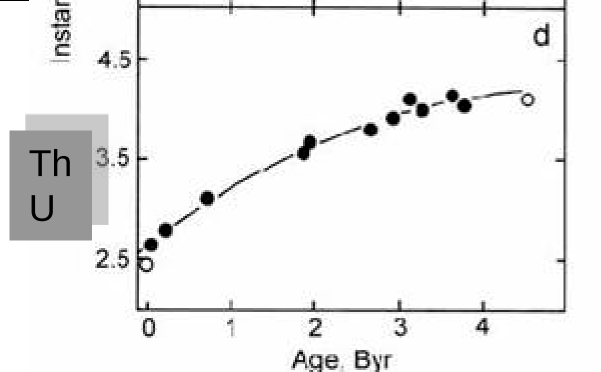
T = initial age/age of the Earth
t = formation age of sample
* = radiogenic (from ^{238}U and ^{232}Th) Pb

Pb-Isotopie und Th/U-Verhältnis, κ





Die fehlende Korrelation zwischen Pb und Sr ist auf das anomale Verhalten von Blei zurückzuführen!



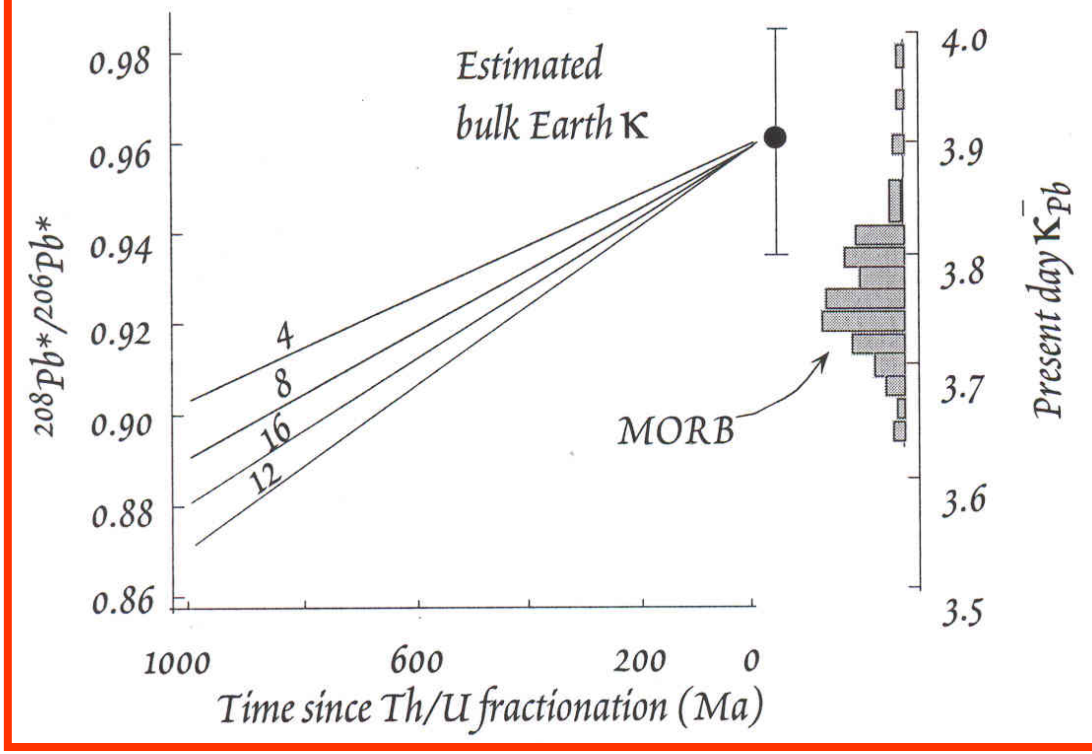
Open system model of Pb isotope evolution of the Earth

Time integrated Th/U ratio (derived from Pb isotope data) of ~3.75 in MORB is much higher than the **„instantaneous“ present-day Th/U ratio of ~2.5!!**

→ MORB reservoir is buffered over geological time by a less depleted reservoir, i.e:

→ MORB source had a brief residence time in the depleted reservoir and spend most of Earth history in a reservoir with a Th/U ratio near Bulk Earth.

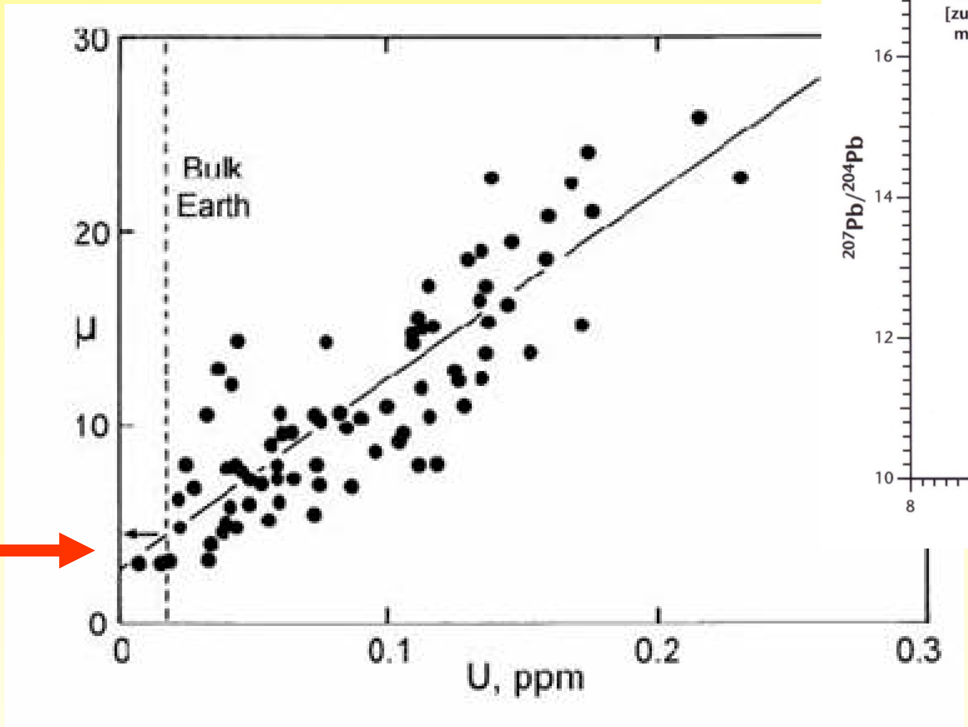
κ (kappa) = atomic Th/U ratio of Earth reservoir



Galer & O'Nions (1985) Nature 316

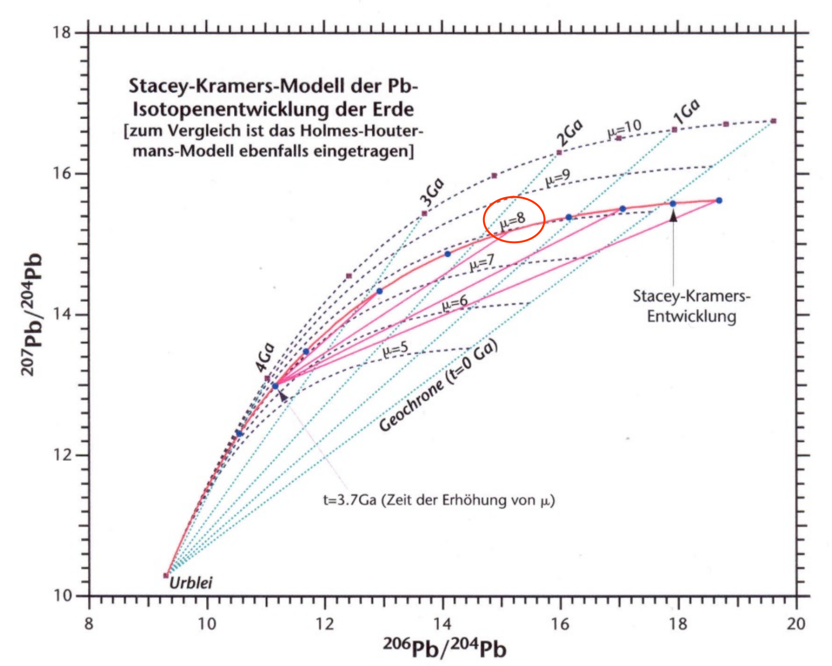
The upper mantle μ-value

$\frac{^{238}U}{^{204}Pb}$



$\mu = 4.5$

Instantaneous μ value in MORB source



White (1993) EPSL 115

Übung:

Das Alter der Erde

In der Stratigraphie eigesetzte geochemische Methoden

Stratigraphie + Datierung =

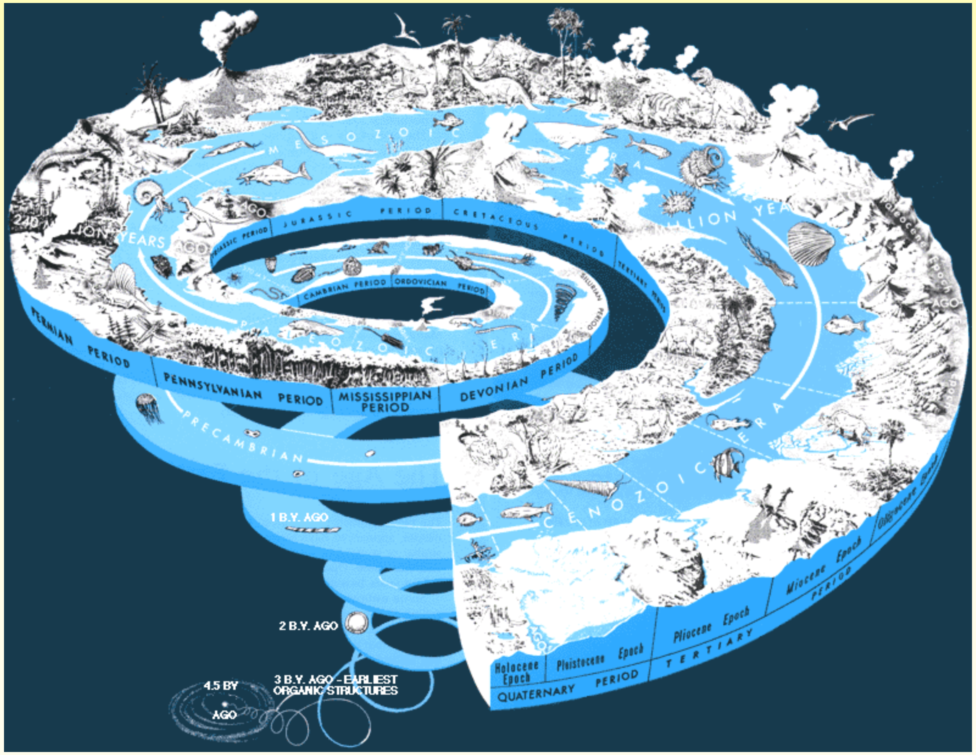
Chronostratigraphie

alle anderen Methoden der Stratigraphie werden in die chronostratigraphische Abfolge eingehängt.

How do we know the age of the Earth?

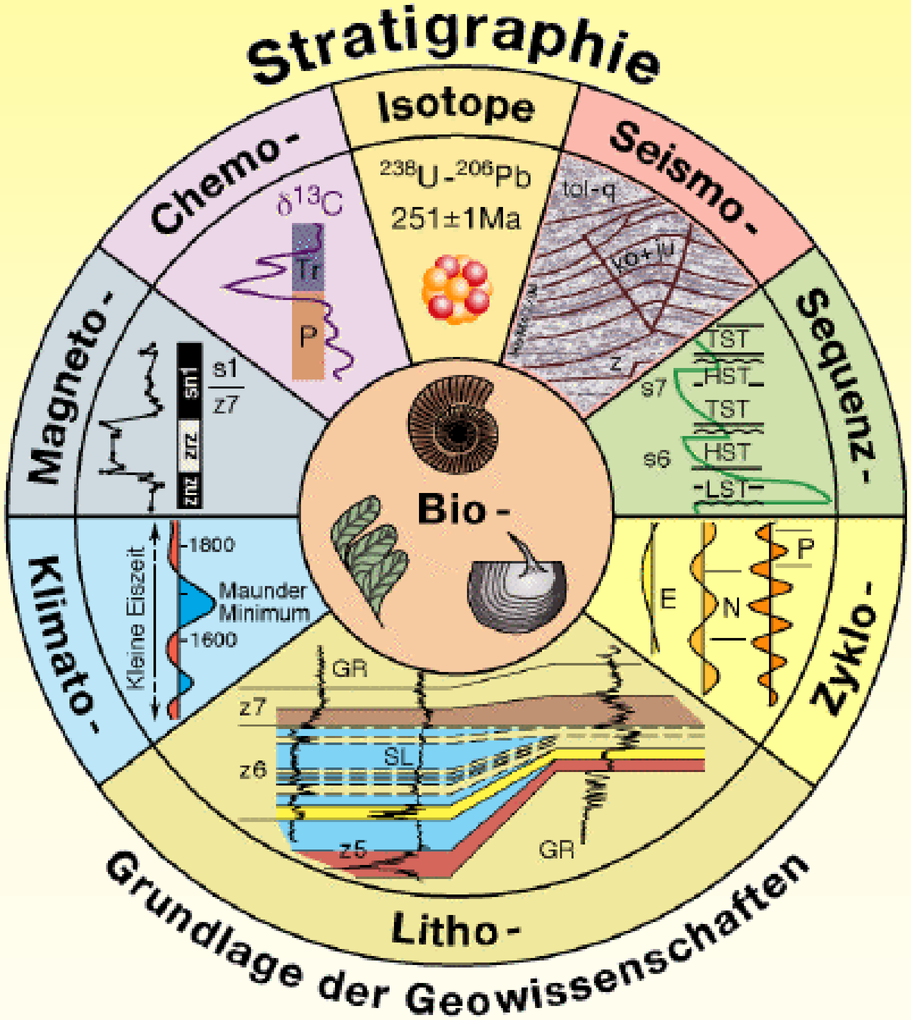
Radiometric dating

A time machine to the past



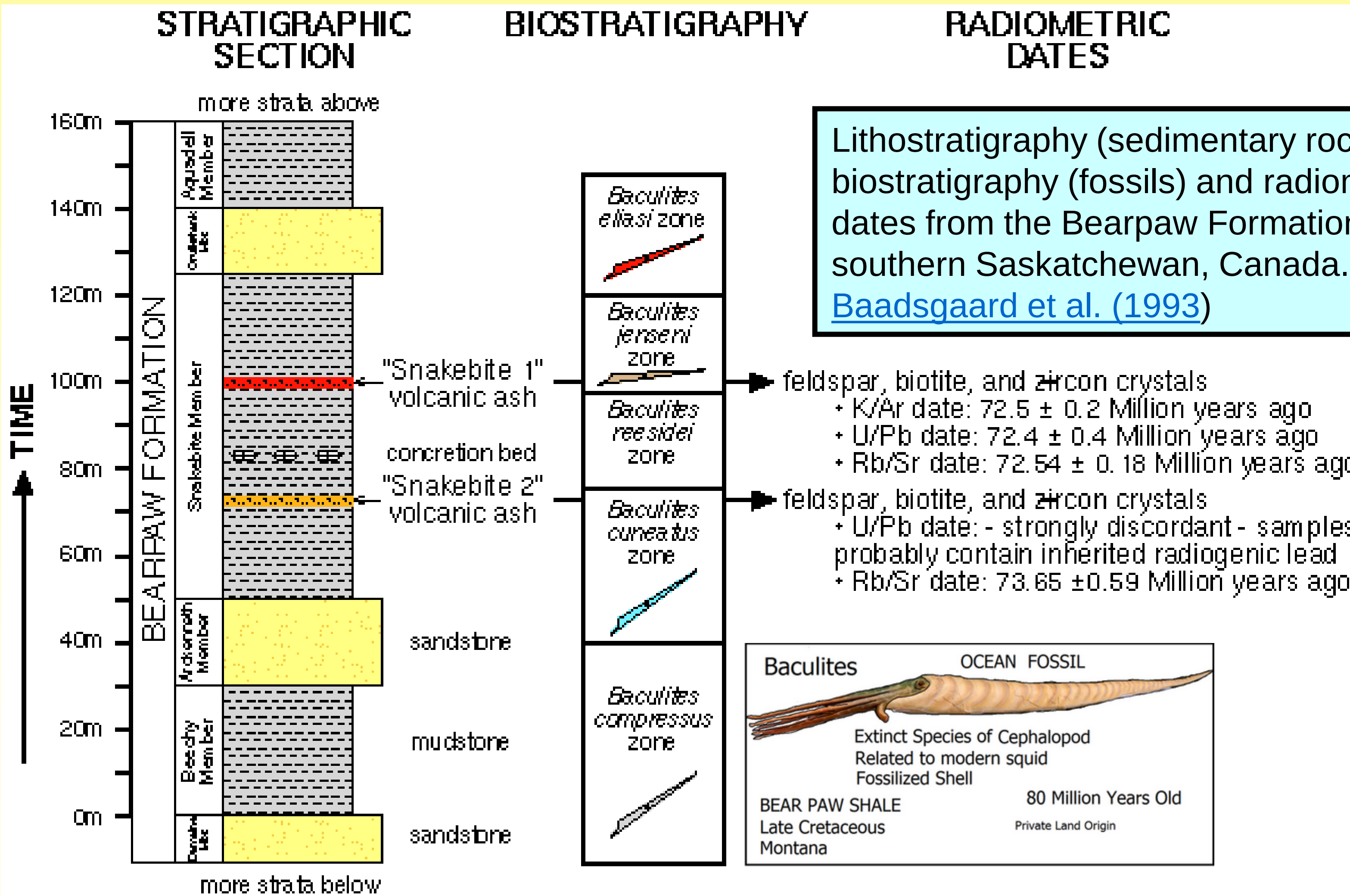
Arthur Holmes 1913:
The age of the Earth

Stratigraphie und Datierung (Chronostratigraphie)



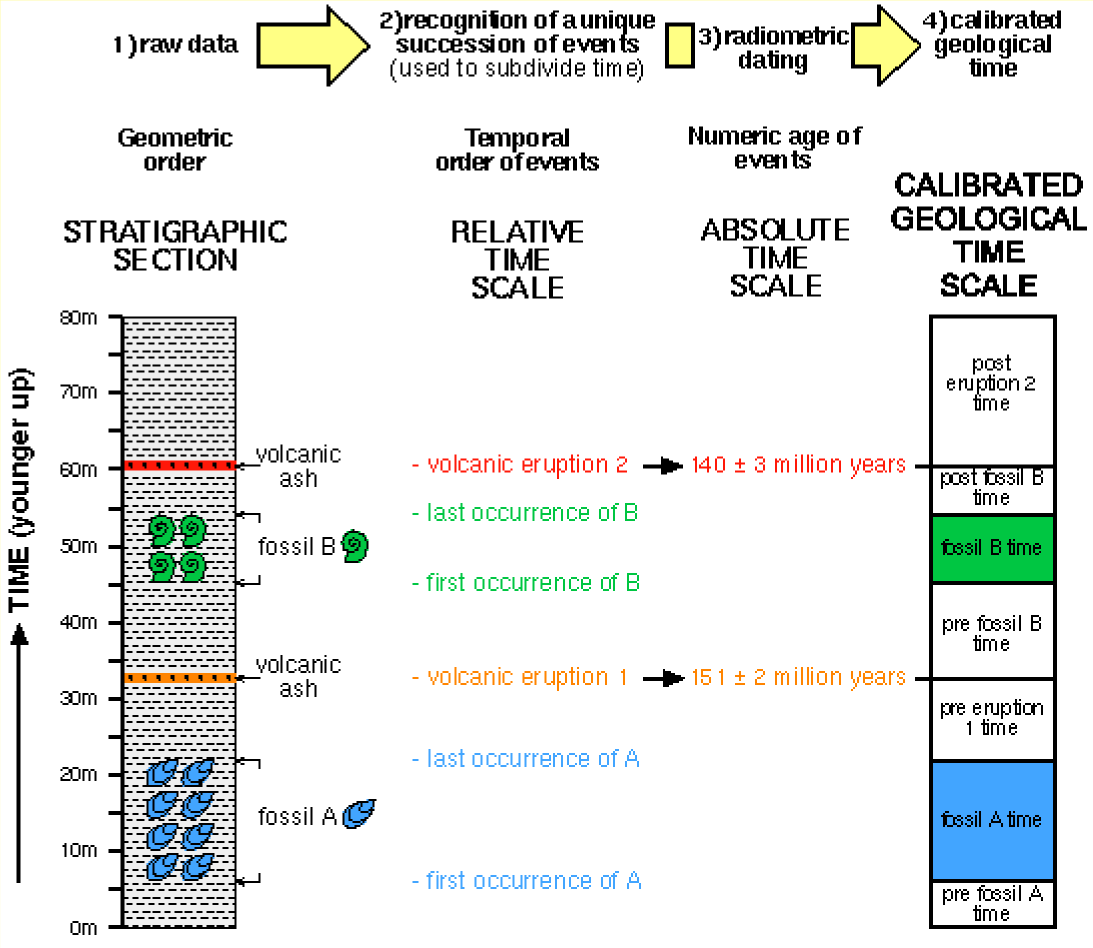
Jutulhogget, Antarctica (photo H. Frimmel)

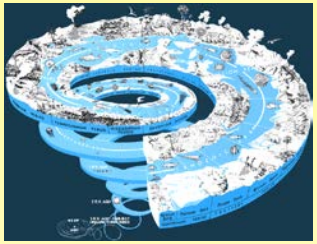
Towards a calibrated geological time scale



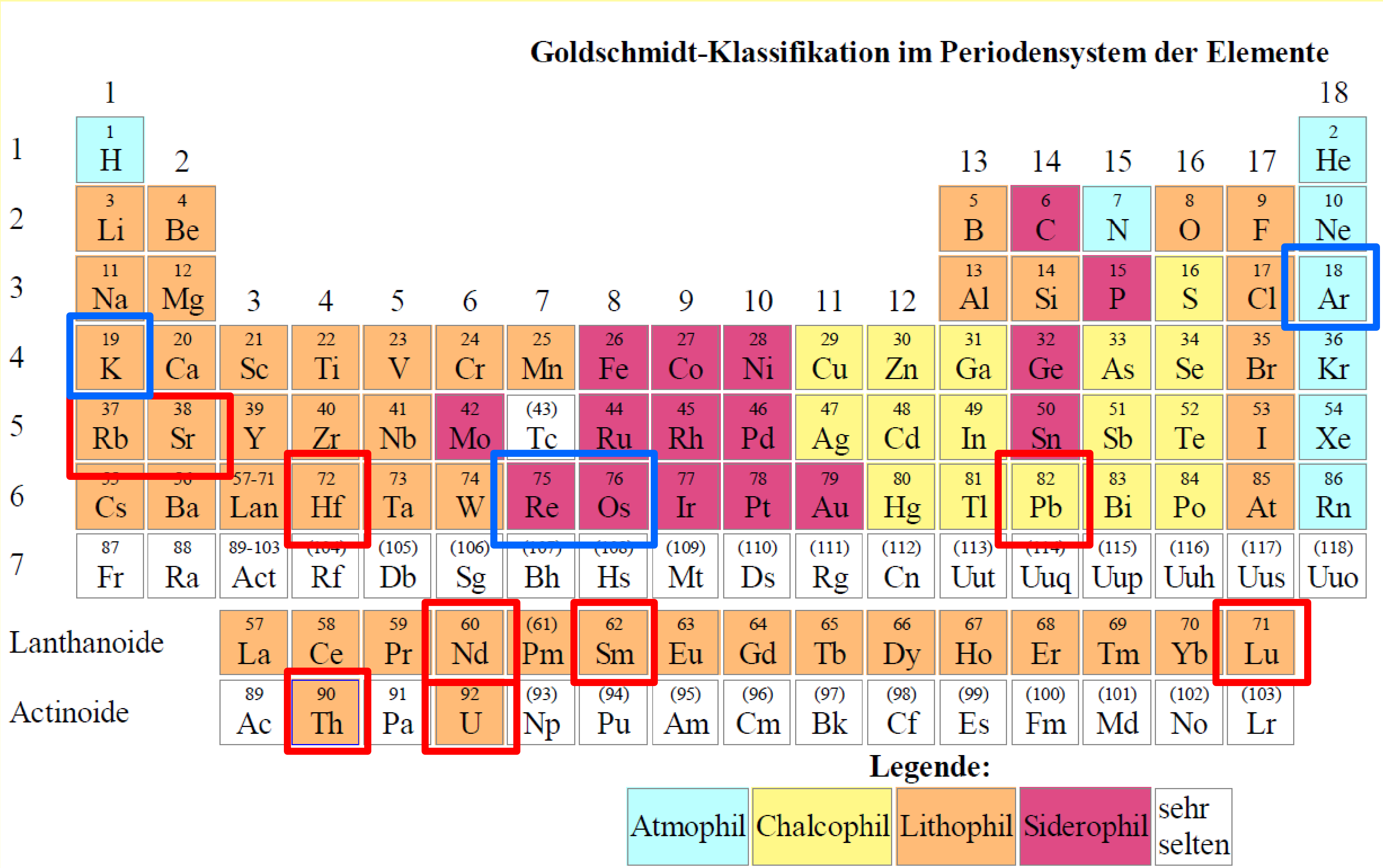
Lithostratigraphy (sedimentary rocks), biostratigraphy (fossils) and radiometric dates from the Bearpaw Formation, southern Saskatchewan, Canada. Baadsgaard et al. (1993)

Towards a calibrated geological time scale



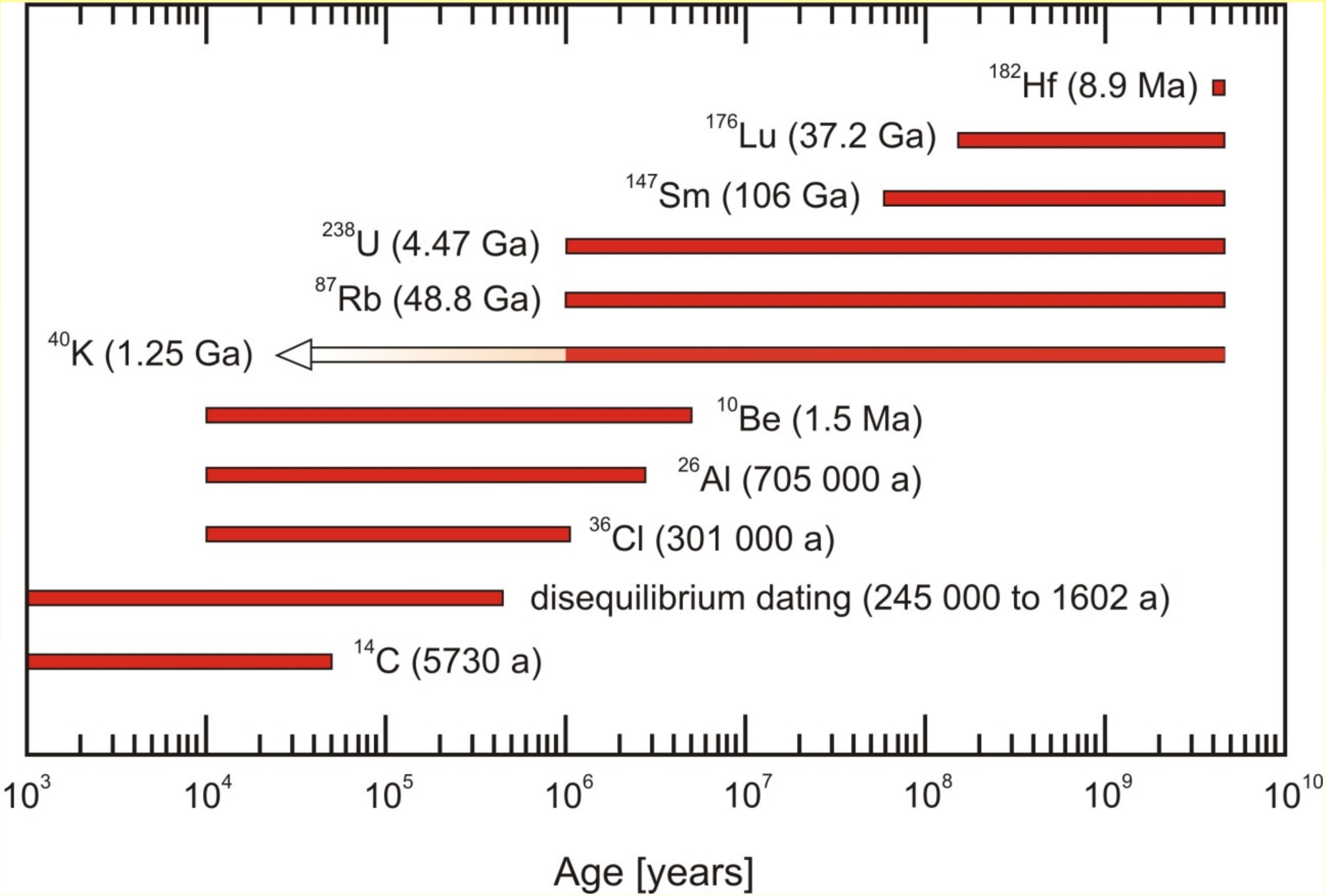


Radiogene Isotopensysteme

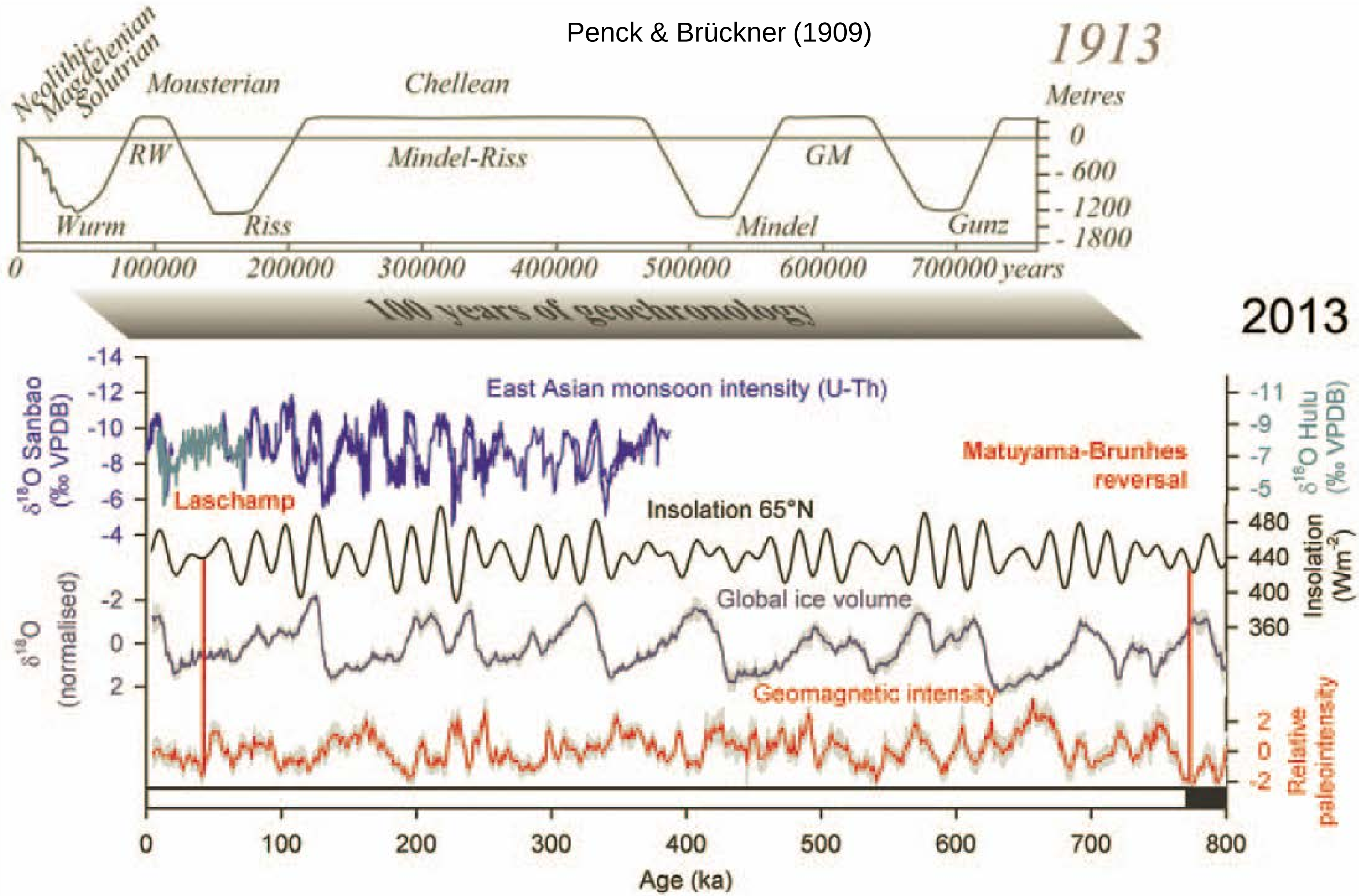


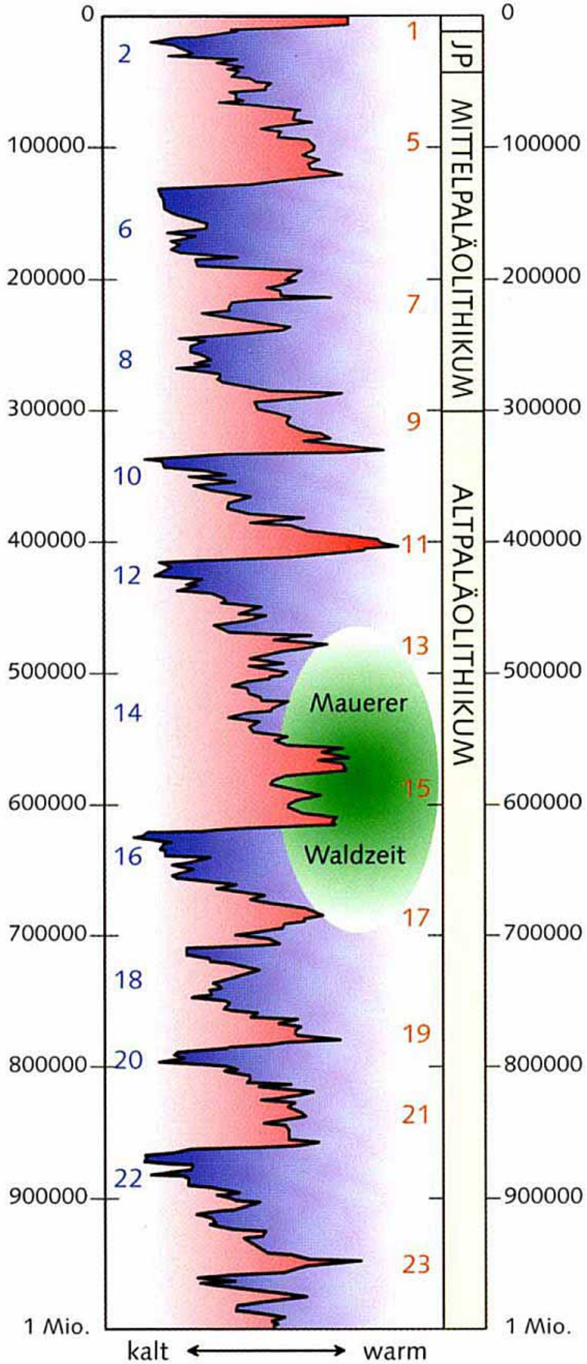
Grafik von: *http://de.wikipedia.org/wiki/Goldschmidt-Klassifikation*

Datierungssysteme



Penck & Brückner (1909)

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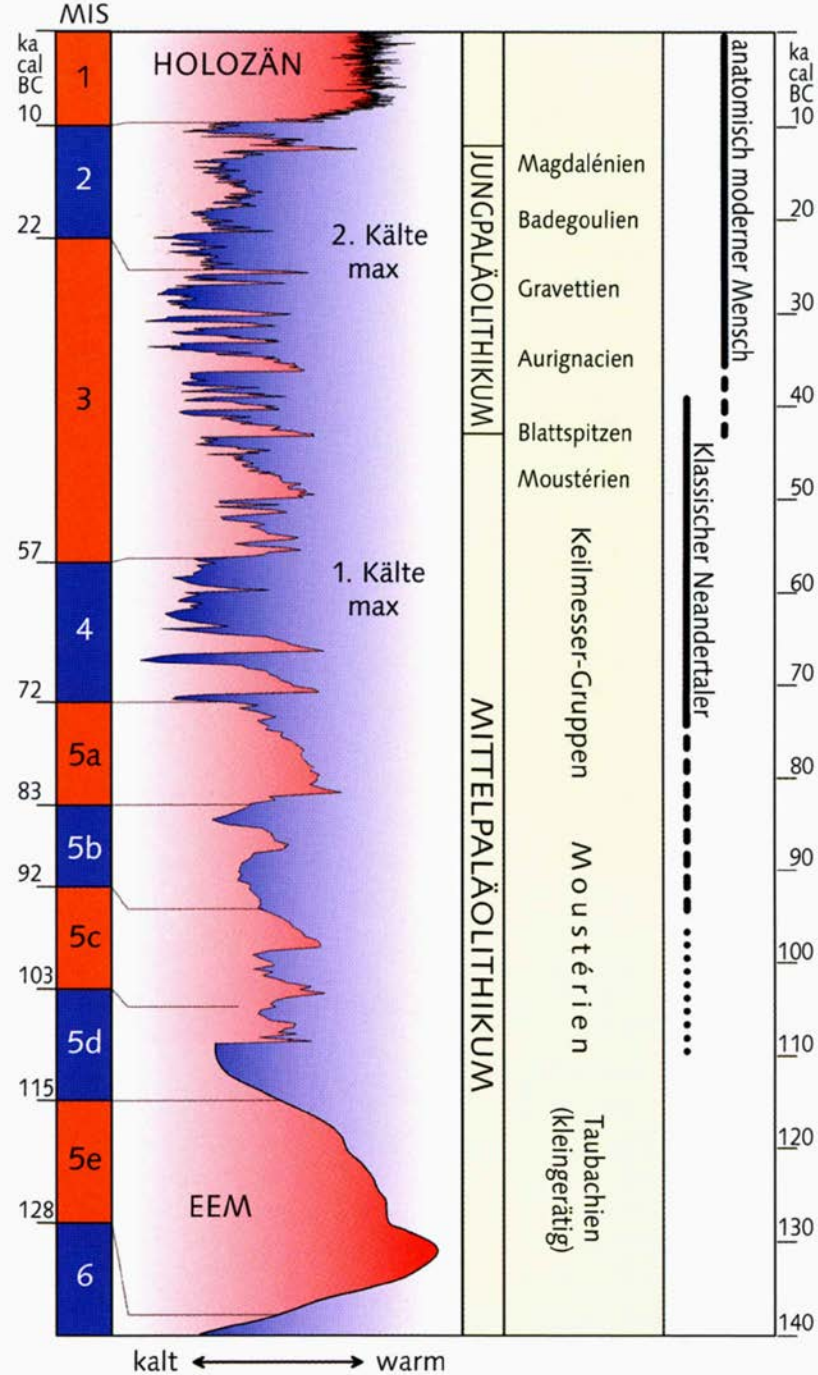
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MITTELPALÄOLITHIKUM
Magdalénien
Badegoulien
Gravettien
Aurignacien
Blattspitzen
Moustérien
Keilmesser-Gruppen
Moustérien
Taubachien (kleingerätig)
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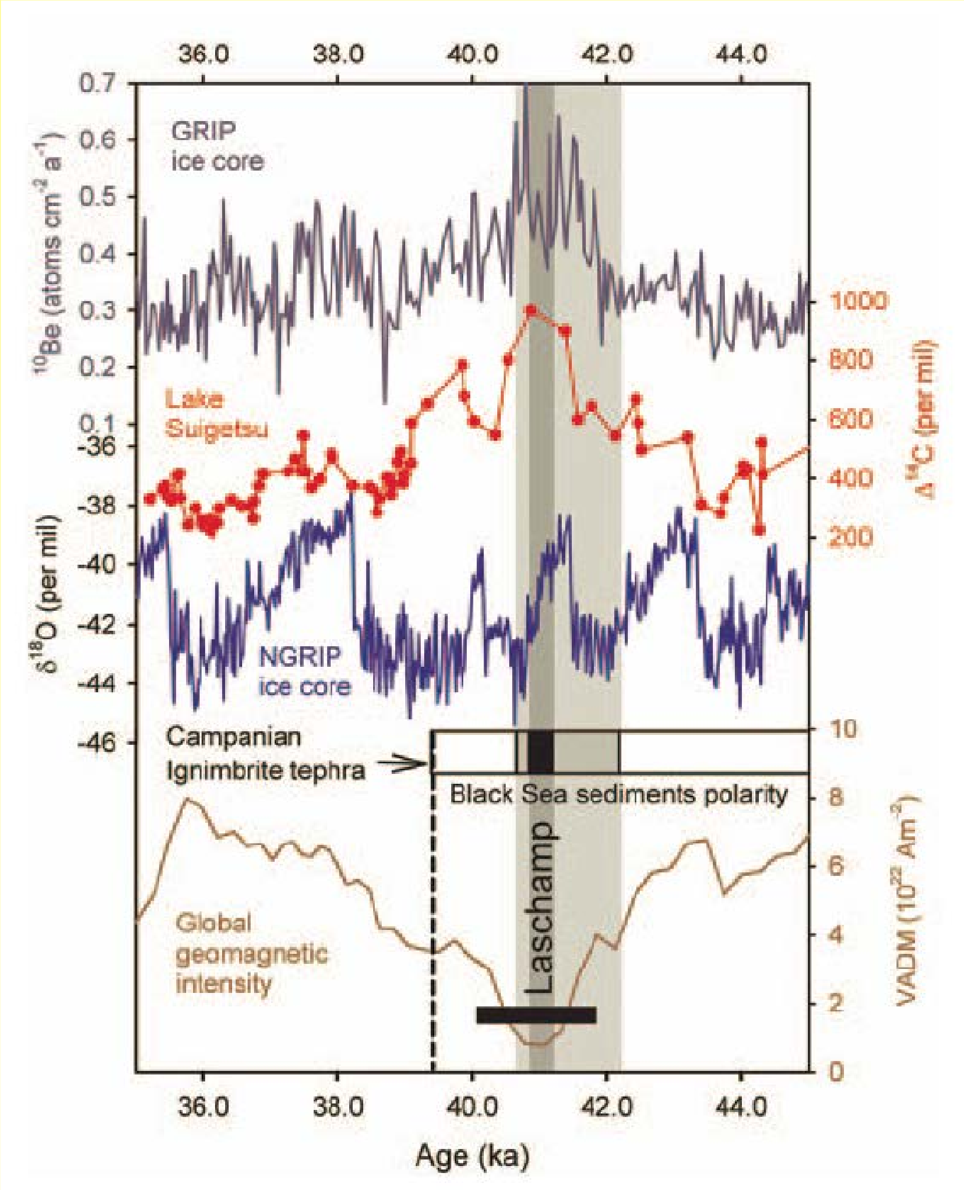


Laschamp

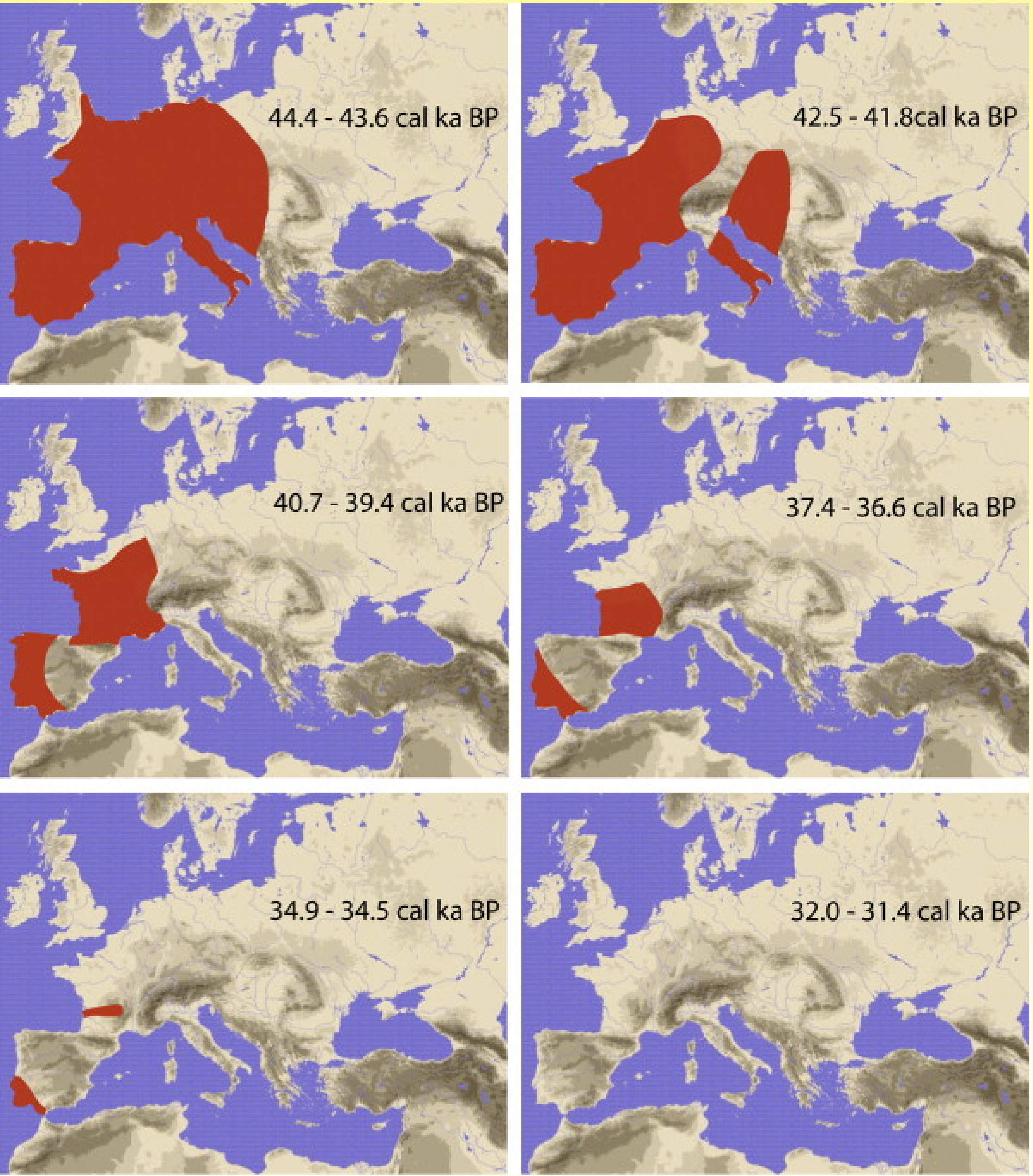
the Earth at 40 ka

short and fast reversal of the Earth's magnetic field

short-term climate variability of the last ice age

and volcanic eruption in Italy

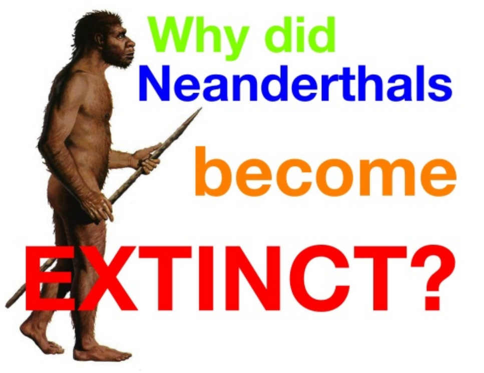
Das Laschamp Ereignis



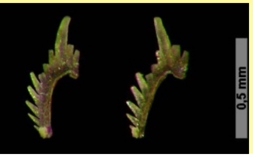
short and fast reversal of the Earth's magnetic field

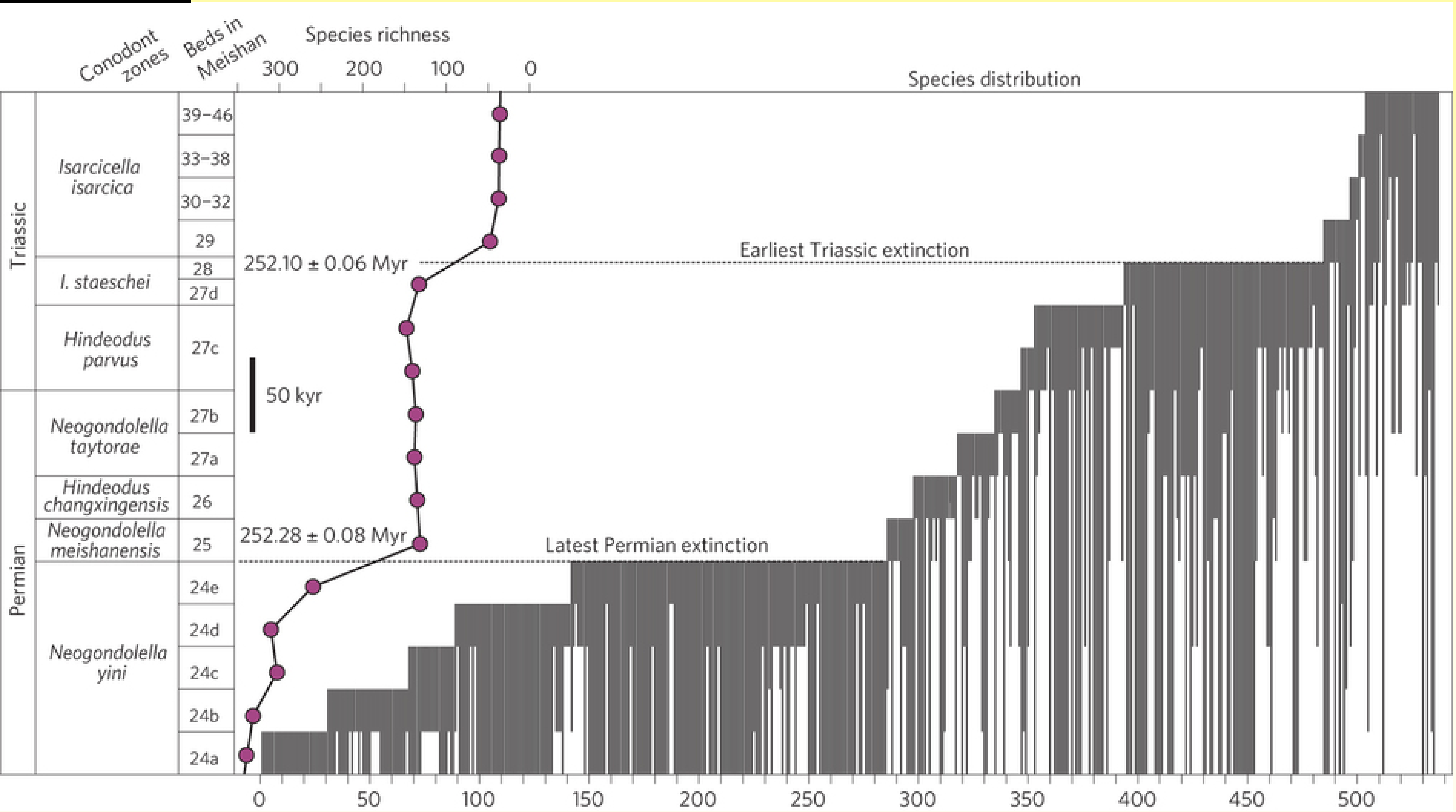
short-term climate variability of the last ice age

and volcanic eruption in Italy

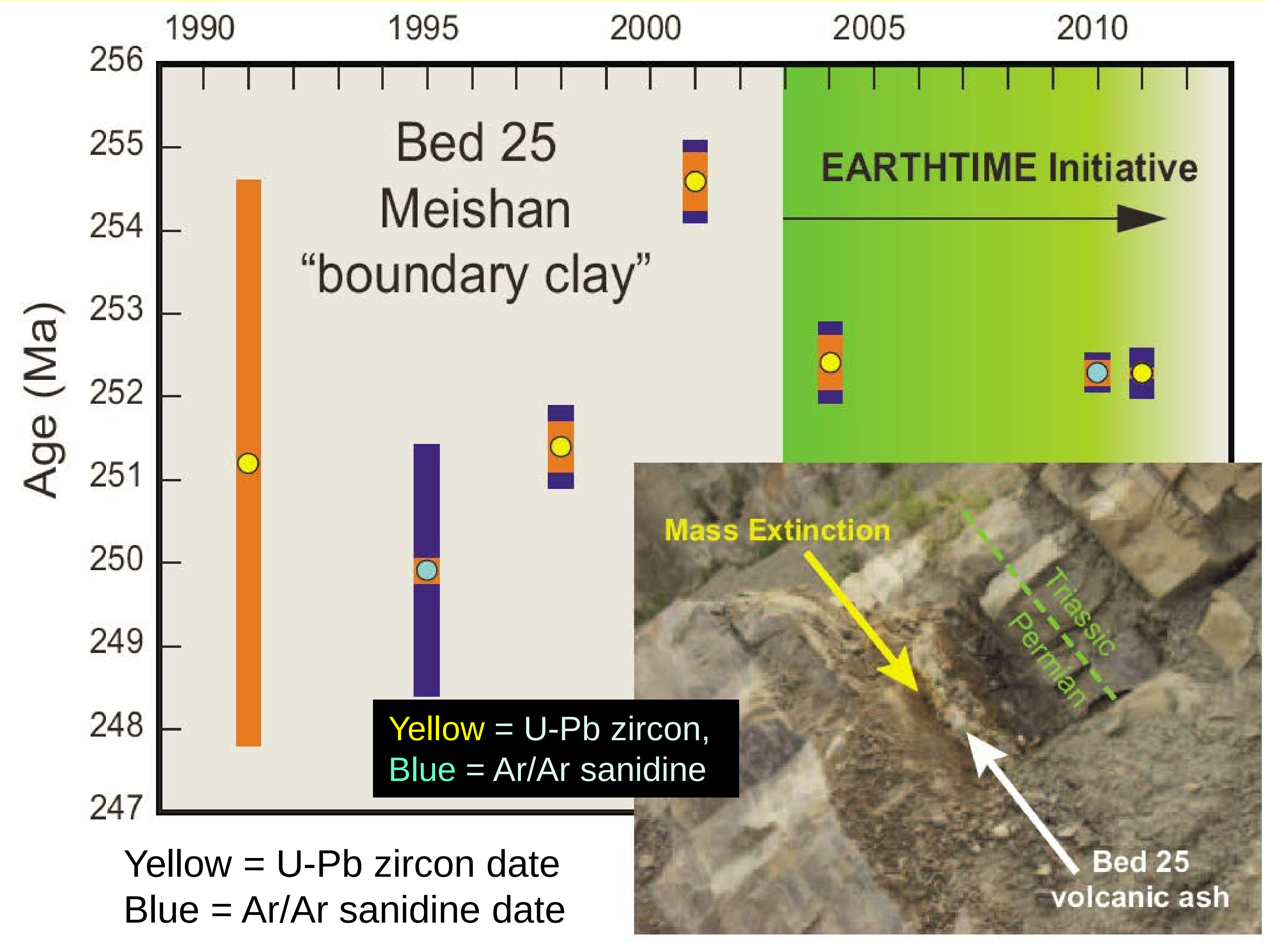


Permo-Triassic mass extinction



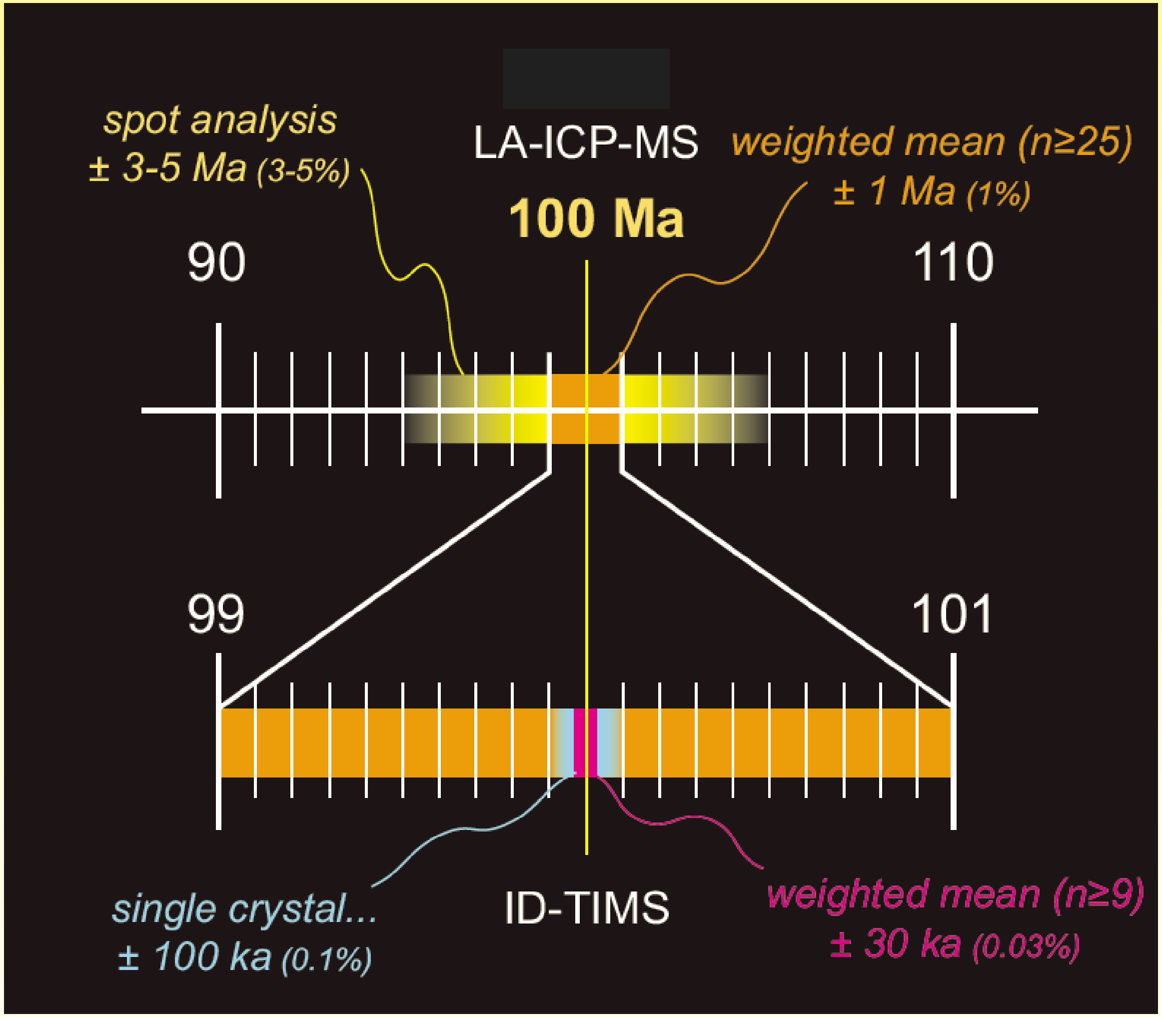


Permo-Triassic mass extinction



Beginning of Siberian Traps volcanism: 250.0 ± 1.6 Ma (Renne et al. 1995)

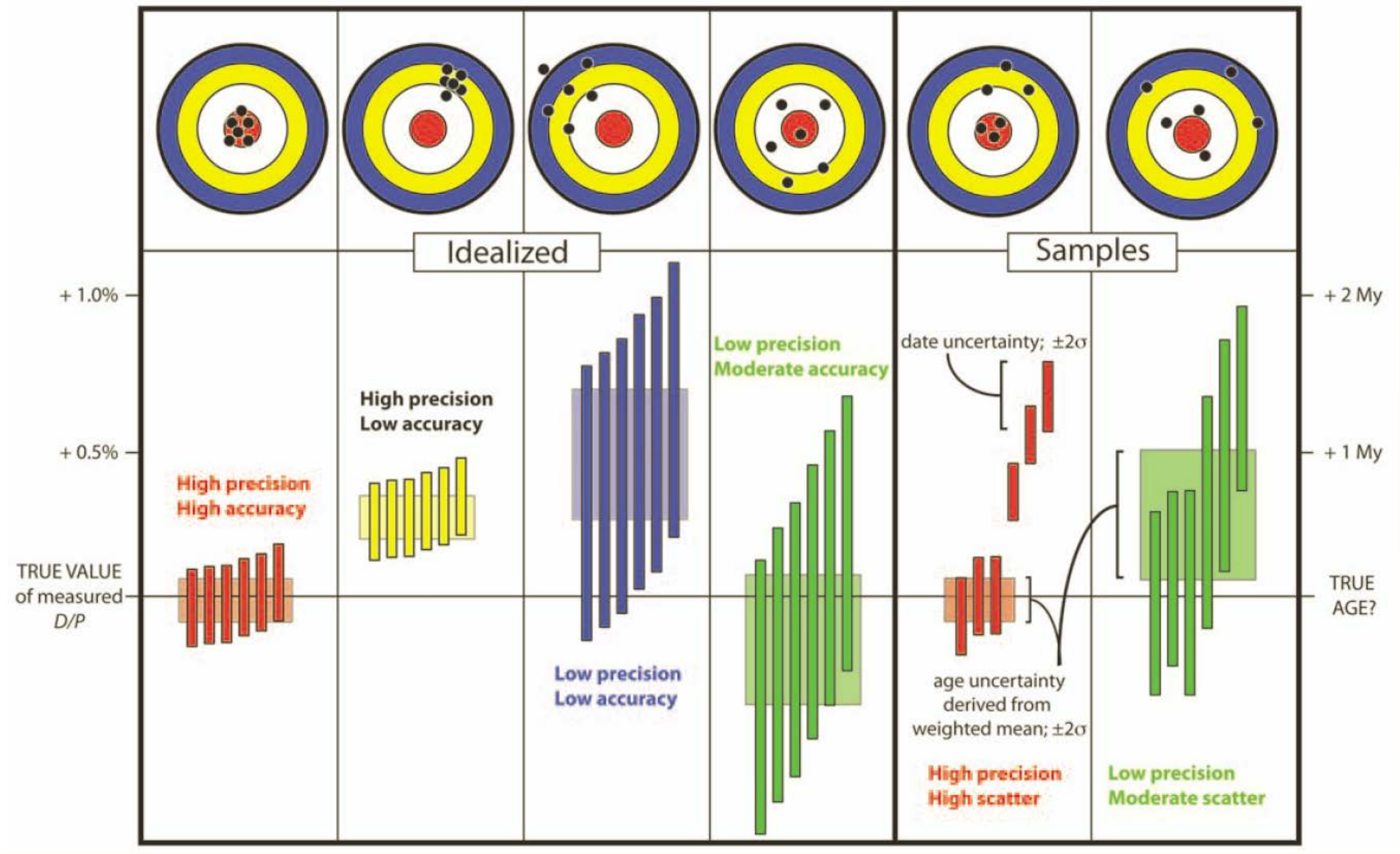
The uncertainty of a data (age) is as important as the data (age) itself
(Ken Ludwig)



The uncertainty of a date is as important as the date itself (Ken Ludwig 2003)

Ideale Welt

Reale Welt



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<td>1800 Ma core with a 220 Ma overgrowth</td>
<td>520 Ma crystal, 300 ky (0.06%) crystallization history</td>
<td>~4 Ma crystal, 300 ky (7.5%) crystallization history</td>
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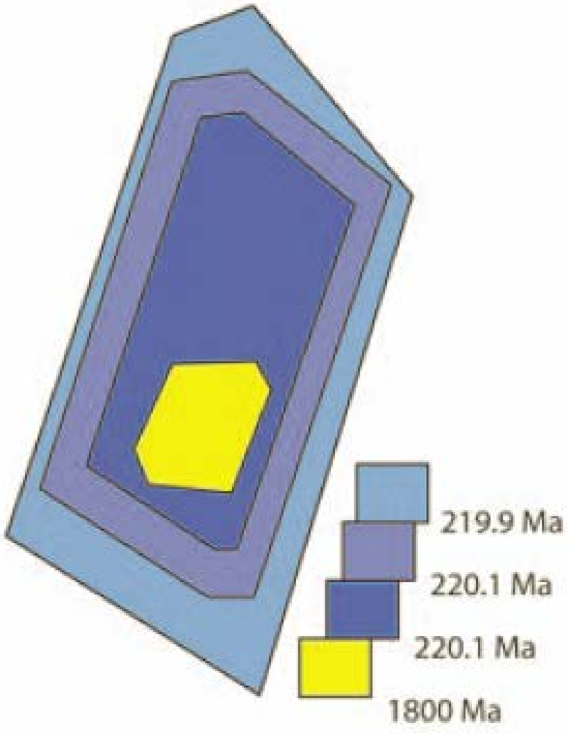
<tr>
<td>
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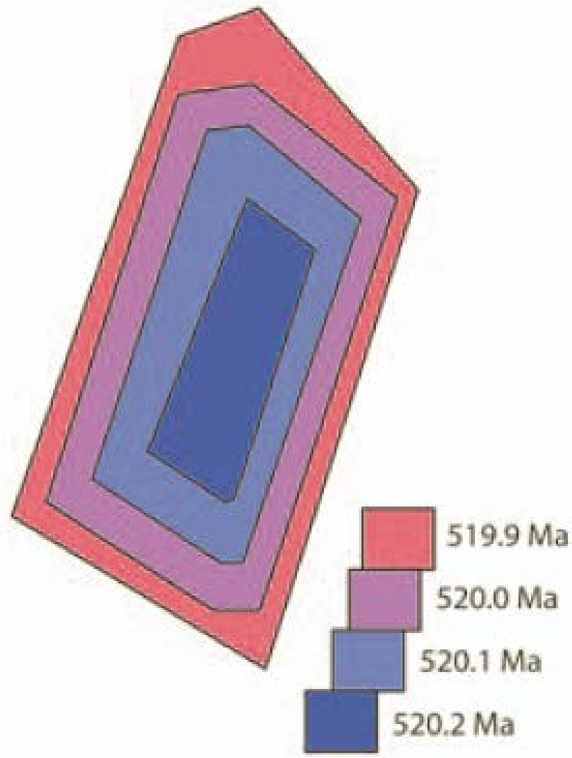
<td>
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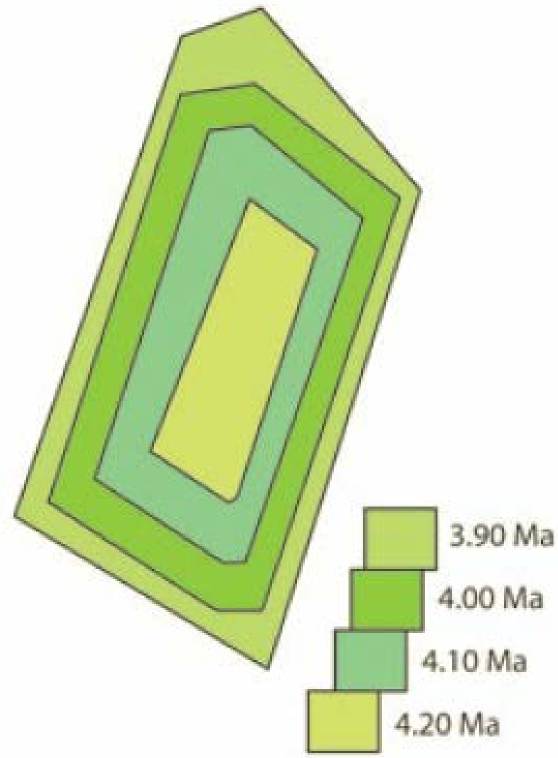
<td>
</td>
</tr>
<tr>
<td>Intracrystal age variation larger than analytical precision of microbeam and ID methods: In situ or microsampling required</td>
<td>Intracrystal age variation unresolvable: whole crystal or in situ sample dates are accurate; weighted mean ages may not be</td>
<td>Intracrystal age variation exceeds analytical precision of microbeam and ID methods: In situ or micro-sampling can resolve growth history</td>
</tr>
</table>

Datingsmethoden und Schließungstemperatur

Closure Temp: the temperature at which a cooling mineral can no longer exchange isotopes with it’s surroundings

Mineral	**Method**	**T (°C)**
Zircon	U-Pb	>800
Monazite	U-Pb	>800
Titanite (Sphene)	U-Pb	600
Garnet	Sm-Nd	>550
Hornblende	K-Ar	500
Muscovite	Rb-Sr	500
Muscovite	K-Ar	350
Apatite	U-Pb	350
Biotite	Rb-Sr	300
Biotite	K-Ar	280
K-Feldspar	K-Ar	200
Apatite	Fission Track	120

Closure temperatures for common minerals for different isotopic systems. Note that closure temperatures for different systems in the same minerals can vary.

Datingsmethoden und Schließungstemperatur